THE

ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY
AND ASTRONOMICAL PHYSICS

VOLUME V — MAY 1897 — NUMBER 5

PHYSICAL AND MICROMETRICAL OBSERVATIONS OF THE PLANET VENUS, MADE AT THE LICK OBSERVATORY WITH THE 12-INCH AND 36-INCH REFRACTORS.

By E. E. BARNARD.

NO OTHER object has caused more controversy and produced more varied testimony in the determination of its rotation period than the planet Venus. This rotation controversy has raged for upwards of two centuries, with fitful periods of quiescence—after some observer more combative than the rest had definitely "settled the question"—only to break out again with renewed virulence when a new champion for rotational honors entered the field.

The periods assigned to the planet vary all the way from twenty-three or twenty-four hours to 225 days. One of the short-period men has gone so far as to produce a period, derived from drawings made a few days apart, with a decimal running into the ten-thousandth of a second, which ought certainly to be convincing enough, as a smaller subdivison of time would be an insensible quantity and ought never to be stickled for in determining the duration of a planetary day.

These discrepancies are due in the main to the difficulty—from various causes—of seeing the markings which really exist on the surface of Venus.

Certainly the prime factor in observations of the surface features of this planet, is a steady atmosphere. Without this one can hope to do little or nothing at all with Venus, no matter how perfect his telescope. When we take into account also that the observations must be made in the daytime to get as high an altitude as possible, we find the difficulty is further augmented, for in the day the atmosphere is never so steady as it often is at night. Take into account, further, that the markings on this planet are exceedingly delicate, with but little contrast, and we have—considering the promise its great brilliancy holds out—perhaps one of the most disappointing objects in the entire heavens.

Venus was frequently observed with the 12-inch refractor at Mt. Hamilton during the years 1888–95, but I never could (with but one exception) satisfactorily see the markings. Vague, indefinite spots were often visible, but it was not possible to see them well enough to identify them for rotational purposes.

The atmospheric conditions at Mt. Hamilton were seldom at all favorable for day observations. The heating of the southern, contrasted with the cooler northern slopes, produced an unsteadiness of the air which was almost always present in the daytime.

There were times, however, when the air was thick with smoke and dust, when the seeing was fairly good. But this condition, though it tended to produce steadiness, was sometimes accompanied with excessively bad seeing, so that it could not always be depended upon as a criterion. A clear blue, transparent atmosphere almost always proved unsteady, and this seemed to hold at night also. Indeed, so marked was this peculiarity that one was wont to say when the sky was a rich dark blue in the day that the night would be bad, so that a dark-blue sky really became synonymous with poor seeing.

The 29th of May, 1889, was remarkable for the thickness of the atmosphere from smoke and dust. One could scarcely see across the cañon so dense was the haze. Examining Venus with the 12-inch on this date I was struck with the remarkably

perfect definition. There was not the slightest tremor of the image. The markings on the surface of the planet were distinctly seen, though they were difficult and very delicate. A careful drawing was made of these details, which were distinct enough to be drawn with perfect satisfaction. This perfection of definition did not last long enough to show any motion in the spots—the ordinary day-seeing soon taking its place.

Venus was looked at at this time with the 36-inch, but the seeing with the great instrument was not perfect enough to show the markings satisfactorily. Indeed, in all subsequent observations of Venus the 12-inch was preferable.

This drawing is herewith presented, and I am satisfied the markings shown exist on Venus and are here closely represented. From their position on the disk it will be seen that they are large broad spots, for they must be greatly foreshortened in their position near the limb.

The circumstances under which this drawing was made are memorable with me, for I never afterwards had such perfect conditions to observe Venus. A close lookout was kept on the planet in hopes of again seeing the spots, but if seen again they were too poorly defined to be recognized. On several dates thereafter when the seeing was fair, the same region seemed to be visible; especially on June 10, 1889, did I have the impression that these markings were present, but the details could not be made out, and probably the three spots were blended into one long vague spot from the lack of definition. On several other dates I seemed to see the same thing, especially on the forenoon of June 12, when a sketch showed about the same appearance.

The planet was watched through many years, but indifferent seeing always baffled one and no satisfaction could be gotten out of it.[1]

In these observations of Venus I have tried various methods to improve the image, such as contracting the aperture of the

[1] On a number of occasions, with both telescopes, I tried to see the dark part of Venus by occulting the bright part, but without success.

object-glass; using a small diaphragm over the eyepiece; using colored glasses, etc. Of these the best results were got by contracting the aperture between the eye and the eye lens of the eyepiece.

I also found it a very great advantage to cover the head and the eye end of the telescope with a large dark cloth to cut out all extraneous light; one has no idea how much this simple method aids in observing a difficult object, either in the daytime or at night, but especially in the day when observing Venus.

In 1895, in conformity with my plan to measure the diameters of all the planets with the 36-inch, I secured a series of measures of the diameter of Venus during the months of May, June, and July, when the planet was approaching inferior conjunction. The customary west wind that springs up nearly every evening during the summer months interfered very much with the observations, often making it impossible to secure measures.

These measures were made with the full aperture of the object-glass except on one date, when it was reduced to twelve inches. A small cap over the eyepiece (next the eye) with a hole in it about $0^{in}.04$ diameter was always used, however. This was very useful in sharpening the image and reducing the glare.

Two magnifying powers were used, 350 and 520. The smaller of these was generally preferred, as the measures were less affected by the oscillation of the image due to wind.

No recognizable markings were seen on the planet during these measures nor at other observations with the 36-inch, though vague suggestions of spots were frequently present.

The measures are of that diameter essentially perpendicular to the orbit of Venus. They are corrected for refraction and in next to the last column are reduced to distance unity ($\triangle$ 1). There does not seem to be any decided systematic difference in the measures due to magnifying power. One or two measures are rather largely discordant, but these can be attributed

to the conditions of observation—shaking of the telescope by the wind or poor definition. No illumination of the wires was necessary and the method of double distance was employed.

In the second column of the following table the standard Pacific times of sunset are given. It will be seen that the measures were made about sunset—some before and some after. It was not possible to measure the planet much after sunset because of the increased disturbance of the image and from the fact that it soon got beyond the reach of the great telescope.

MEASURES OF THE DIAMETER OF VENUS IN 1895.

S. P. T.	Sunset	Mag. power	See-ing	Observed	Δ 1	Resid.
May 6d 7h 6m	6h 59m	350	4	14″.43	17″.30	+0″.10
" 6 7 16	....	520	3	14 .61	17 .51	−0 .11
" 12 7 30	7 4	520	3	14 .99	17 .35	+0 .05
" 13 6 56	7 5	520	3	15 .04	17 .30	+0 .10
" 13 7 3	....	350	3	14 .83	17 .06	+0 .34
June 2 6 54	7 20	520	2–3	17 .16	17 .23	+0 .17
" 2 7 2	....	350	2–3	17 .19	17 .25	+0 .15
" 3 7 20	7 20	350	3	17 .52	17 .45	−0 .05
" 9 6 48	7 24	350	3	18 .44	17 .51	−0 .11
" 9 6 58	....	520	3	18 .27	17 .35	+0 .05
" 10 7 58	7 25	350	2	19 .26	18 .13	−0 .73
" 16 6 17	7 27	350	3	19 .36	17 .32	+0 .08
" 16 6 20	....	520	2	19 .35	17 .31	+0 .09
" 17 7 5	7 27	350	2	19 99	17 .73	−0 .33
" 17 7 10	....	520	2	20 .10	17 .83	−0 .43
" 24 7 25	7 29	350	4	20 .59	17 .10	+0 .30
" 30 6 25	7 29	350	3	22 .23	17 .39	+0 .01
" 30 6 30	....	520	3	22 .33	17 .47	−0 .07
July 1 7 23	7 29	350	4	22 .33	17 .28	+0 .12
" 1 7 29	....	520	3	22 .65	17 .53	−0 .13
" 7 7 55	7 28	350	3–4	24 .38	17 .67	−0 .27
" 8 7 27	7 28	350	2–3	24 .03	17 .23	+0 .17
" 14 7 10	7 26	350	3–4	25 .57	17 .09	+0 .31
" 14 7 18	....	520	3–4	25 .63	17 .13	+0 .27
Mean.....					17″.397	

The mean of these measures reduced to distance unity gives 17″.397 for the diameter of Venus, which corresponds to an actual diameter of 7826 miles.

NOTES ON THE MEASURES.

1895, May 6. Planet clearly defined. No spots seen. Measures good.
" 6. Image unsteady. Seeing getting bad.
" 12. Very heavy wind shaking telescope. Image oscillating badly.
" 13. Measures very good.
1895, May 13. Not a tremor of the image from wind or vibration of the telescope.
June 9. Image jumping and fluttery.
" 10. Wind shaking telescope.
" 16. High northwest wind, but not striking telescope.
" 24. Wind shaking telescope too much to use higher power.
" 30. Wind shaking telescope.
July 1. No wind.
" 14. Slight wind shaking telescope. Aperture reduced to twelve inches No definite markings.

In *A. N.*, 3204, Bd. 134, Dr. L. Ambronn gives his measures of the diameter of Venus, made during 1892, with the great heliometer at Göttingen. I am indebted to his paper for the following list of previous measures of the diameter of Venus, including his own measures in 1892.

These measures will be interesting in comparison with those made with the 36-inch.

(1) E. Hartwig, Breslau heliometer	17".67
(2) E. Hartwig's reduction of the Oxford measures	17 .582
(3) E. Hartwig, from double-image observations by Kaiser	17 .409
(4) E. Hartwig, nine measures in Bahia-Blanca	17 .406
(5) B. Peter, two measures in Bahia-Blanca	17 .216
(6) F. Küstner, two measures in Punta Arenas	17 .312
(7) A. Auwers, measures during transit	16 .801
(8) L. Ambronn, Göttingen heliometer	17 .711
Mean	17".389

It will be seen that these are in very close agreement with my measures with the 36-inch in 1895.

YERKES OBSERVATORY,
April 1897.

NOTES ON THE DETERMINATION OF THE FOCUS OF AN OBJECTIVE.

By H. C. Lord.

In photographing stellar spectra with the compound star spectroscope, it is of the utmost importance that the slit be placed accurately in the focal plane of the great objective, for the particular part of the spectrum to be examined. This is especially true when the so-called achromatic objective is corrected for the visual portion of the spectrum. As I have been unable to find any published directions as to the proper method of accomplishing this result, which were at the same time specific and accurate, or any experiments which would show the precision to be expected, I have thought that my experience with different methods tried and the results obtained might not be without interest to the readers of the Astrophysical Journal.

The instruments used were the twelve and one-half inch equatorial and large star spectroscope of the Emerson McMillin Observatory, which are fully described in the Astrophysical Journal, **4**, 1. The battery of two prisms was used in every case. A less dispersion might have been better, but I was anxious to use the instrument under the same conditions as those in which it was to be used for regular work.

The first method tried was that due to Professor Young and described in the *American Journal of Science*, No. CXIV, namely, of placing the limb of the Sun over one-half the slit and focusing until the line of division of the bright and faint spectra appeared sharp. The seeing was never good enough for this method to give even an approximate place. The same method was tried, using the Moon in place of the Sun. The results were much more accurate, but on account of the faintness of the lunar spectrum it was difficult to accurately focus the observing telescope. The following plan was then tried: The reading of the scale on the draw-tube of the observing telescope,

when $H\beta$ was in focus, the line used in all my experiments, was determined from a number of pointings on the Sun. These were made at widely differing temperatures and the setting found to be constant within $0^{mm}.1$. At night, with a small electric lamp placed in front of the slit so as to show a continuous spectrum and the prisms so placed that $H\beta$ was under the cross wires and the observing telescope set at the proper scale reading, the eyepiece was focused on the cross wire, which appeared dark on a colored field. The telescope was then turned upon a star and the whole collimator racked in and out until the spectrum appeared linear where it was crossed by the cross wire. Five pointings were made, the eyepiece being focused between each pointing. Temperatures were read from two thermometers graduated to ½° F., placed one near the objective and one on the spectroscope, the mean of the two being taken as the temperature. In this manner fairly accordant results were obtained at first. The results are given in the table below together with the focus computed by a formula whose derivation will be described later. After October 10 my eye had a long rest until November 6, when a focus for 50° F. was found which was higher than that previously found for 62° F. Similar results were obtained on November 9. I attributed this to the inability of the observer to prevent his eye accommodating itself to slight changes in focus.

This method was then abandoned and the following photographic method was adopted. The scale reading of the camera for the $H\beta$ focus was determined as before from the Sun, both photographically and by means of a small eyepiece slide which takes the place of the plate holder. Both methods gave the same result. The slit of the spectroscope was then set parallel to an hour circle, in order to have the resulting photograph as narrow as possible, the telescope turned on Polaris and a series of from five to seven exposures given with the collimator set at a different point for each. These points differ by $0^{mm}.5$ in all except those made on November 30, which differed by a single millimeter. Temperatures were read from two ther-

mometers placed as before, readings being taken at the end of each exposure. The average of all was taken as the temperature. At the end of the exposure the artificial $H\beta$ was photographed on the plate. The distance from the $H\beta$ line to the point on the spectrum where it was narrowest was then measured. This could not be told closer than the nearest millimeter, though the results were read to the nearest fifth millimeter. In selecting this point the eye is guided by three factors. The spectrum should be the narrowest, the edges the sharpest, and bearing in mind the color sensitiveness of the plate used, the density should be the greatest. Let this measured distance be d, s the scale reading at which the negative was made, s_0 the scale reading for the given temperature when $H\beta$ is in focus, m s a constant depending upon the slope of the color curve at that point; then evidently $s = s_0 + dm$. d and s are given by observation. Each plate gives one equation and from these equations the values of s_0 and m were calculated by the method of least squares. Each series of plates were measured on three different days.

This method has proved entirely satisfactory, and the results are given in the following table. The 4th, 5th, and 6th columns give the focus determined from any set of plates on each of the three days that it was measured. The 7th gives the means of I, II, and III. From these means the temperature equation $s_0 = 20^{mm}.6 + 0^{mm}.037\ (T^{\circ} - 0^{\circ})$ was computed by the method of least squares. The 7th column gives the value of s_0 computed from the formula for the given temperature. The columns 10, 11, and 12 give the values of m. Column 14 gives the temperature at which the visual observations were made, 15 the observed focus, 16 the focus computed from the preceding formula. This table brings out several facts: (1) That the eye tends to give a constant error in the position of the focus amounting to nearly 1^{mm}, a quantity too large to be neglected. (2) It shows that the photographic method gives much more accordant results than the visual method. (3) The constancy of the value of m, taken in connection with the close agreement of the results for the focus, will tend to show that the accuracy reached is real

PHOTOGRAPHIC.

Date	No. plates	Temp. F.	Focus for $H\beta$				Comp. focus	C—O	M		
			I	II	III	Mean			I	II	III
1897—January 25...	6	— 5°.5	20mm.3	20mm.5	20mm.2	20mm.3	20mm.4	+0mm.1	—0.31	—0.35	—0.32
1897—*February 26.	6	+16 .6	20 .9	20 .8	20 .9	20 .9	21 .2	+0 .3	—0.31	—0.31	—0.37
1897—*February 27.	5	+17 .7	21 .4	21 .4	21 .5	21 .4	21 .3	—0 .1	—0.30	—0.32	—0.36
1896—November 30.	5	+17 .8	21 .4	21 .1	21 .3	21 .3	21 .3	±0 .0	—0.37	—0.33	—0.33
1897—February 27..	5	+18 .0	21 .6	21 .8	21 .5	21 .6	21 .3	—0 .3	—0.31	—0.37	—0.32
1896—December 1..	5	+18 .5	21 .4	21 .4	21 .5	21 .4	21 .3	—0 .1	—0.38	—0.25	—0.29
1897—February 27..	5	+19 .0	21 .4	21 .4	21 .1	21 .3	21 .3	±0 .0	—0.35	—0.32	—0.35
1896—December 3..	5	+24 .5	21 .7	21 .4	21 .7	21 .6	21 .5	—0 .1	—0.27	—0.40	—0.35
1897—*February 24	6	+30 .5	21 .4	21 .4	21 .7	21 .5	21 .7	+0 .2	—0.34	—0.22	—0.34
1897—March 7.....	5	+34 .5	21 .9	21 .8	21 .7	21 .8	21 .9	+0 .1	—0.31	—0.32	—0.30
1896—December 5..	6	+42 .0	22 .4	22 .0	22 .0	22 .1	22 .2	+0 .1	—0.44	—0.37	—0.39
1896—December 9..	7	+44 .0	22 .4	22 .1	22 .4	22 .3	22 .2	—0 .1	—0.27	—0.34	—0.34

*On these dates camera set 0mm.1 wrong.

NOTE.—On February 27 three sets of negatives were made.

and not simply an accident of observing. It should be stated that though during this set of observations the spectroscope was frequently removed from the telescope, the system of stops provided on the instrument kept the distance, spectroscope to objective, constant.

VISUAL.

Date	Temp. F.	Obs. focus	Comp. focus	C—O
1896—September 1.....	62°.0	21mm.4	22mm.9	+1mm.5
1896—September 4.....	63 .2	22 .2	22 .9	+0 .7
1896—September 9.....	72 .7	22 .5	23 .3	+0 .8
1896—September 19.....	51 .8	21 .1	22 .5	+1 .4
1896—September 22.....	46 .0	20 .5	22 .3	+1 .8
1896—September 25.....	65 .2	22 .0	23 .0	+1 .0
1896—September 26.....	70 .3	22 .2	23 .2	+1 .0
1896—October 3.....	51 .8	21 .7	22 .5	+0 .8
1896—October 4.....	55 .0	21 .4	22 .6	+1 .2
1896—October 8	47 .4	21 .3	22 .4	+1 .1
1896—October 9	49 .0	21 .2	22 .4	+1 .2
1896—October 10	52 .2	21 .1	22 .5	+1 .4
1896—November 6....	49 .8	22 .0	22 .4	+0 .4
1896—November 9....	33 .6	21 .2	21 .8	+0 .6
1896—November 9....	33 .9	21 .4	21 .9	+0 .5

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.

III. THE INSTRUMENT AND OPTICAL SHOPS, AND THE POWER HOUSE.[1]

By GEORGE E. HALE.

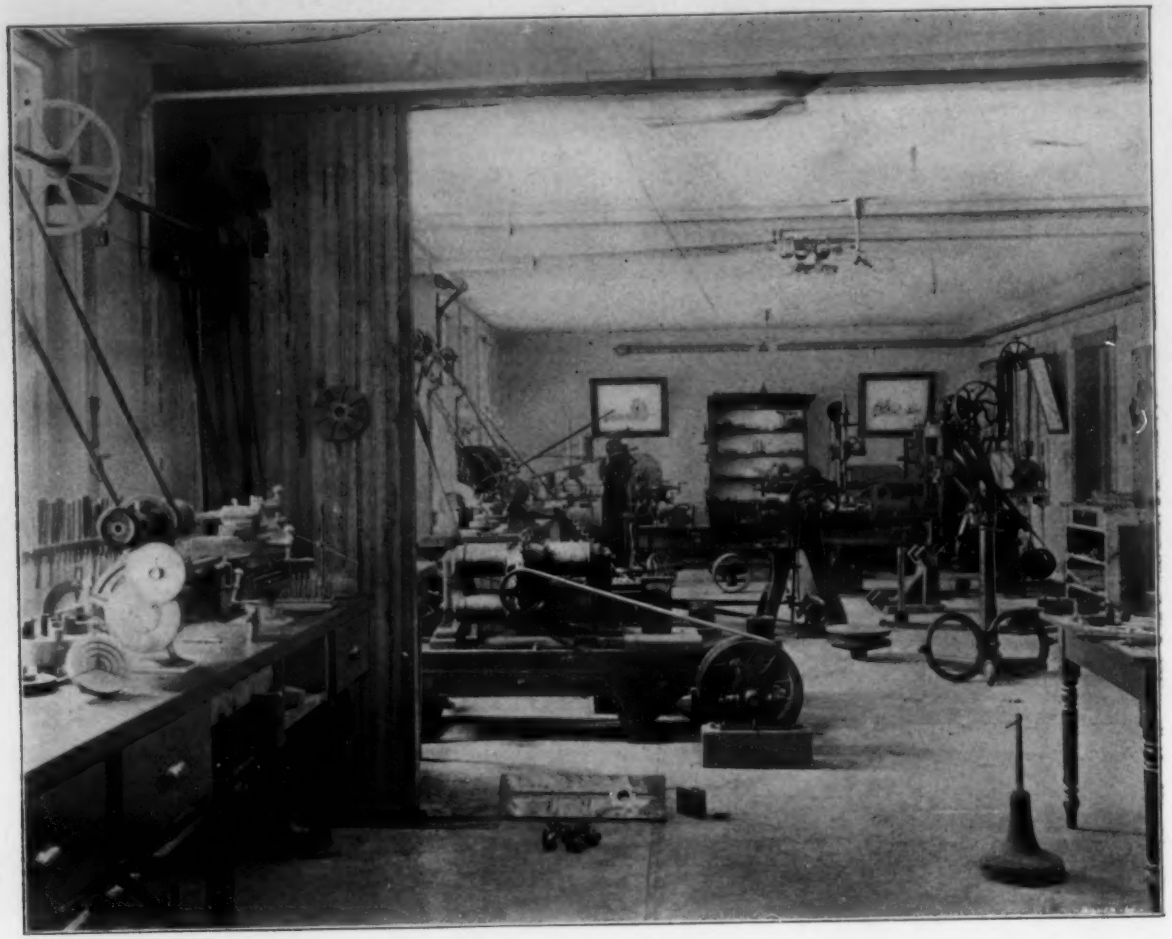
THE INSTRUMENT SHOP.

MANY of the problems which confront the modern astronomer and astrophysicist require for their solution the invention of new methods of research and the construction of instruments of special design. This is particularly true in astrophysical work, and an observatory in which such investigations are to be carried on must be prepared to supply the needed apparatus. Fortunately for the progress of science in the United States, the instruments manufactured by the best firms in this country are not surpassed, if they are equaled, by those made abroad. As this is true of both the optical and mechanical parts, it is evident that no institution having the necessary funds at its disposal need have any difficulty in procuring the apparatus it requires.

The writer had found at the Kenwood Observatory, however, that while the principal instruments could be most advantageously obtained from Brashear and Warner & Swasey, it was necessary to have a workshop in which a skilled mechanician was almost constantly employed in constructing the numerous pieces of apparatus required in the solar and spectroscopic work. Those who have devised new instruments of research know only too well that it is frequently necessary to completely rebuild a piece of apparatus, or at least to make extensive alterations in it, before the expected results can be obtained. If an instrument is built under the eye of its designer, the ideas which may suggest themselves during its construction can be embodied in it at a minimum of cost. In fact, the very opportunity to see

[1] For previous articles in this series see the March and April numbers of this JOURNAL.

PLATE XX.



INSTRUMENT SHOP OF THE YERKES OBSERVATORY.

each part made is not to be undervalued, for one not only obtains in this way a very intimate acquaintance with every detail, but is also much more likely to find important improvements suggesting themselves, which can be at once realized. For much experimental work it is also quite unnecessary to go to the expense of purchasing a finished piece of apparatus, when something answering equally well can be put together under one's own direction in a very short time. Another great advantage of having an instrument shop is the fact that repairs can be made at the moment they are needed, so that an important investigation need not suffer unduly from the results of an accident.

It seemed evident that if an instrument shop had proved to be indispensable at so small an institution as the Kenwood Observatory, it would be necessary to provide the Yerkes Observatory with the very best facilities for mechanical work. The machine tools which had been used for some years at Chicago were an engine-lathe, a shaper, and a small speed lathe. Subsequently there had been added an 8-inch Rivett "Precision" lathe and a Brown & Sharpe universal milling machine. These, with a large number of hand tools for wood and metal working, were available for the purposes of the Yerkes Observatory. It was decided to add to them at once a planer and a drill press, together with a circular saw and speed lathes for pattern work.

It had at first been planned to have the workshop in the power-house, but after it had been found that for various reasons this could not be done, rooms on the lower floor of the Observatory building were selected for the purpose. Professor Wadsworth, who had been placed in charge of the work of designing and constructing instruments, laid out the plan of the shop. A room 18 × 54 feet, occupying the southeast quarter of the ground floor,[1] was devoted to the metal-working tools, and smaller rooms, in the hall adjoining this on the east, were fitted up as pattern shop and forge room. To lessen the effects of vibration of the machinery, the cement floors of the shop are

[1] See Plate XI in the April number of this JOURNAL.

separated from the walls by strips of soft wood. For the same reason the main shaft, which runs the entire length of the large room, and extends through the partition into the pattern shop, is not hung from the ceiling, but supported from the floor. The countershafts, also, are mounted on floor supports, no shafting of any kind being attached to the ceiling. The results of this plan are very satisfactory, and up to the present time no traces of vibration have been detected, although sensitive instruments have been used in various parts of the building.

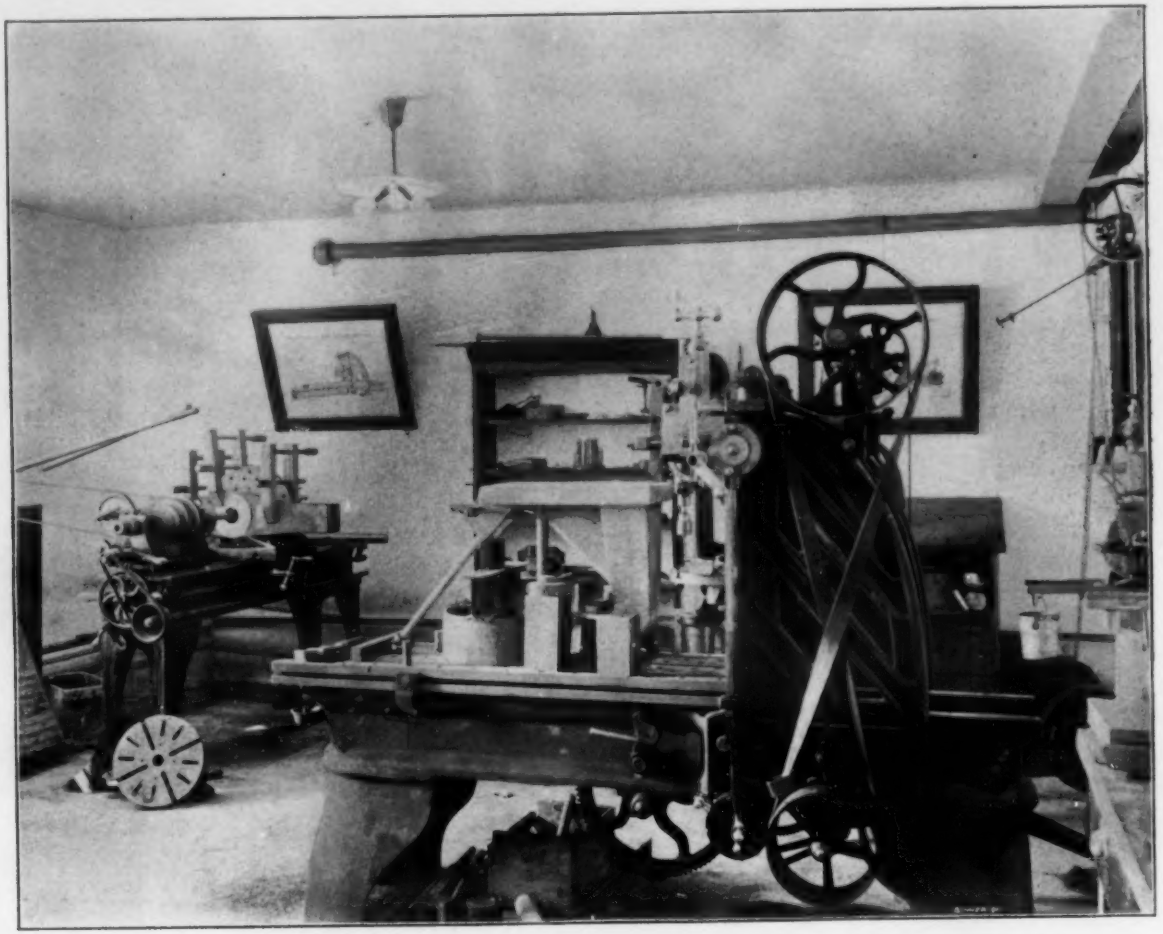
As the photographs show (Plates XX and XXI), the heavier machinery, consisting of a 16-inch Blaisdell engine lathe, Prentice drill press, 20 × 20 Wheeler planer, Brown & Sharpe universal milling machine, and shaper, have been grouped in the west half of the large shop. In this part of the shop there are also an emery grinder, speed lathe, bench for filing and chipping, and soldering bench. The motor which furnishes the power is a transformed 70-light Weston dynamo formerly used by the writer at the Kenwood Observatory to generate the current employed in his studies of the spectrum of the electric arc. But few alterations were required to adapt it to its present purpose, for which it serves very well.

The more delicate instrument work is done at the east end of the shop in a room separated from the space just described by a glass partition.[1] A filing bench runs the entire length of the south wall of this room, and is carried around on to the east wall. Upon this bench is mounted an 8-inch Rivett "Precision" lathe fitted with grinding attachment, Horton chuck, step chuck, and a set of split chucks. The change gears permit threads to be cut on both the English and metric systems. The shop is provided with a good collection of small tools.

The machine tools in the pattern shop consist of a circular saw with iron tilting table, and a large face-plate lathe of nine feet swing designed for pattern work and built by our own mechanicians. There is also a cabinetmaker's bench and a good assortment of wood tools. The adjoining forge room

[1] Not completed when the photograph reproduced in Plate XX was taken.

PLATE XXI.



INSTRUMENT SHOP OF THE YERKES OBSERVATORY.

contains a forge with hand blower, and a blacksmith's anvil with the necessary small tools.

The shops have been fitted up during the past winter by Professor Wadsworth and the two mechanicians. Although this has necessarily taken up much time, opportunity has nevertheless been found for other work. Among the machines and instruments constructed may be mentioned the 9-foot pattern lathe, planer chuck, large spectroscope,[1] rotating shutter for solar photography, set of universal clamps and supports for the laboratories, and an alt-azimuth mounting for a 24-inch reflector.[2] The 12-inch telescope of the Kenwood Observatory has been remodeled to adapt it to the higher latitude and different conditions of work of the Yerkes Observatory. The large spectroheliograph has also been partly rebuilt, and a grinding machine for the optical shop is now in process of construction. In addition to this much repair work has been done.

Two skilled mechanicians are employed in the shop. A recent gift from a friend of science in Chicago for the express purpose of constructing a machine for ruling gratings, designed by Professor Wadsworth, will now render possible the employment of a third mechanician, whose entire time will be devoted to this work. An interferometer will be required in perfecting the adjustments of the ruling machine. This will be constructed first in order that it may also be employed in Professor Wadsworth's determinations of the absolute wave-lengths of lines in the infra-red spectra of the elements. In addition to the ruling machine the most important instrument now being built in the shop is a 24-inch heliostat, castings for which are shown on the engine lathe and planer in Plate XXI.

THE OPTICAL SHOP.

According to a well-known saying, a reflecting telescope can be successfully used only by its maker. While this is of course not strictly true, the history of the larger reflectors has been

[1] Shown in Plate XVII in the April number of this JOURNAL.

[2] Shown in Plate XV in the April number of this JOURNAL.

such as to emphasize the meaning which it is intended to convey. No one can appreciate so well as the maker the peculiar sensitiveness of specula, and no one is so well prepared to overcome the difficulties encountered in their use. As the light-grasping power of specula depends upon the condition of the reflecting surface, it is of great importance that the silver film be kept highly polished, and that it be replaced by fresh silver when necessary. Recognizing from the outset the superiority of reflectors for stellar spectroscopic work,[1] the writer has always planned that the Yerkes Observatory should be provided with a large reflecting telescope as soon as circumstances would permit. It was thought best to secure the services of an optician to grind and polish the mirror at the Observatory, and subsequently to keep it in good condition. There was much other work for an optician to do, and it will be gathered from what follows that this plan of supplying our own needs, so far as it can be done to advantage, has not proved unprofitable.

Mr. G. Willis Ritchey, at one time assistant in the Cincinnati Observatory and later in charge of the woodworking department of the Chicago Manual Training School, was engaged in the spring of 1896 as optician. For many years Mr. Ritchey had carried on optical work as an amateur, and at the time of his appointment he had completed an excellent speculum of twenty-four inches aperture and only eight feet focus.[2] A 24-inch speculum of the same focal length as the Yerkes telescope (61 feet) now used in the writer's bolometric work, was made by Mr. Ritchey in a few weeks. This mirror well illustrates one of the most important advantages of the optical shop. For obvious reasons a professional optician frequently objects to sending out work which he regards as in any sense incomplete. As a bolometer one-sixth of an inch wide was to be used at the focus of this mirror, it is evident that it was wholly unnecessary to go to the expense of parabolizing. The desired spherical

[1] See a paper "On the Comparative Value of Refracting and Reflecting Telescopes for Astrophysical Investigations," this JOURNAL, **5**, 119, 1897.

[2] Now temporarily used on an alt-azimuth mounting in the heliostat room.

figure was obtained in a very short time, and the total cost was only a small fraction of the regular optician's price for a finished parabolic mirror of the same dimensions. Later, if it is desired to use the mirror for other purposes, the parabolic figure can easily be obtained.

Almost the entire work of fitting up the unfinished north room (20 × 70 feet) which was chosen for the optical shop, has been done by Mr. Ritchey. Two rooms were partitioned off for the grinding machines. The larger of the two (20 × 21 feet) is to contain a machine designed by Mr. Ritchey for grinding and figuring a 60-inch glass disk. This large grinding machine is designed so as to allow the mirror, which lies horizontally during the grinding and polishing, to be quickly inclined to a nearly vertical position when it is to be tested. Two cranks, with adjustable throw or stroke, are used to give the desired motion to the grinding and polishing tools, the mirror, as usual, revolving slowly beneath these tools. The arms which communicate the motion of the cranks to the tools, can be lengthened or shortened while the machine is in motion, thus allowing changes in the position of the tools upon the glass to be made with ease and smoothness. One of these arms also carries the mechanism which rigorously controls the slow rotation of the grinding and polishing tools; and the same arm carries a lever for counterpoising a part of the weight of the tools during the process of grinding and polishing. Since the large disk of glass for the 60-inch mirror weighs nearly a ton, and the grinding tools several hundred pounds each, a strong lever, properly mounted and counterpoised, is necessary for lifting the glass and tools on and off the machine. The metal parts of this machine are being made in the instrument shop, and the heavy wooden frame is to be built by Mr. Ritchey.

The smaller room, 12 × 20 feet, contains the grinding machine used in making the two 24-inch mirrors already referred to. Mr. Ritchey will soon make on this machine a 24-inch flat mirror for the new heliostat. A line shaft running near the floor under a long bench by the windows is driven by an electric

motor. The grinding machines are connected with this shaft by means of a set of friction disks, so arranged that the speed of the machines can be varied through a wide range by the simple motion of a lever. Thus a variation of from 6 to 60 strokes of the tool per minute can be obtained while running.

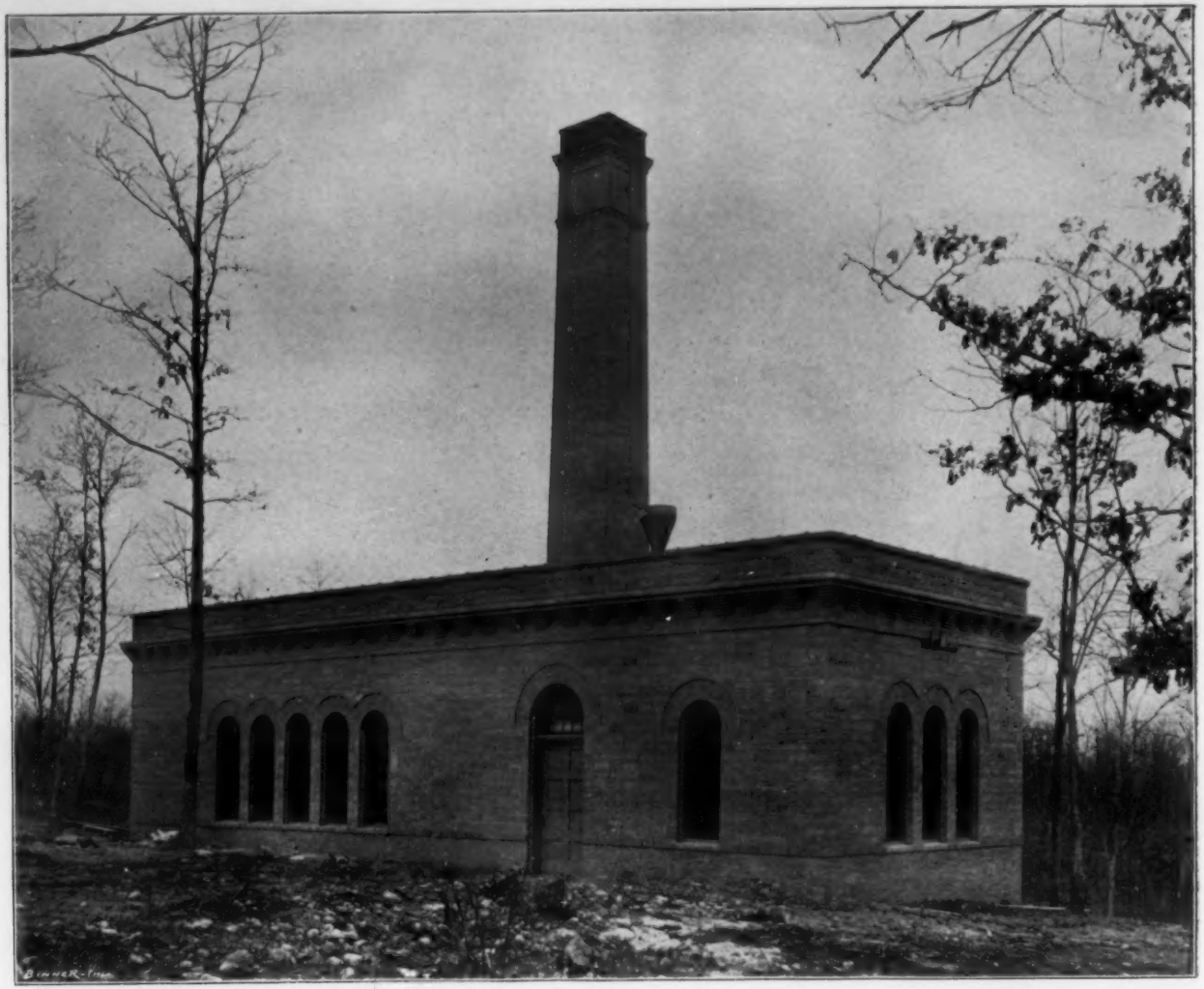
The optical shop was prepared for use by covering the brick walls with two thicknesses of heavy building paper, separated from the wall and from each other by wood strips, thus leaving two air spaces. The lapped joints of the paper were firmly fastened with outside wood strips, and the whole was varnished. As a further means of maintaining the temperature constant, and of excluding dust, the windows of the grinding rooms are provided with a second inner sash, built in practically air tight. The line shaft is carefully boxed in, and the cement floor is painted. Both grinding rooms have doors in their west walls, which are opened when mirrors are to be tested by Foucault's method. By opening doors in the adjoining halls, a space 175 feet long becomes available for testing purposes. The room next the smaller grinding room contains the electric motor, and is fitted up with table and sink for silvering, the preparation of pitch tools and similar work.

A disk of glass 60 inches in diameter and 8 inches thick is expected to arrive shortly from the plate-glass works of St. Gobain, France. As soon as the large grinding machine is finished, this will be made into the large speculum for stellar spectroscopic work referred to above.

THE POWER HOUSE.

Power is needed in the Yerkes Observatory for many purposes. The motions of the 40-inch telescope are produced by five different electric motors, and the rising-floor and 90-foot dome are operated by two motors of greater horse-power. As has been stated, the instrument and optical shops receive their power from electric motors and the entire building is lighted by incandescent lamps. In order to furnish suitable means of generating power at a distance from the Observatory, Mr. Yerkes

PLATE XXII.



POWER HOUSE OF THE YERKES OBSERVATORY.

has provided a separate brick building (Plate XXII) for the power and heating plant. The equipment of this building, all of which was generously presented to the Observatory by Mr. Yerkes, consists of two 8×10 Ideal engines, each carrying a direct-connected Siemens & Halske dynamo, with a capacity of 200 amperes at 125 volts. The switchboard is so arranged that either dynamo can be used to furnish both power and light while the other is idle. Steam is supplied by two 14×48 tubular boilers, equipped with Gulickson smokeless furnaces and grates. A duplex feed pump, connected with a feed-water heater and oil separator, furnishes the boilers with water. A well under the power-house, 165 feet deep, fed by springs, insures a constant water supply. From it a deep-well pump forces the water to three large receiving tanks in the Observatory building. The further equipment of the power-house includes automatic appliances for the control of steam and water, so arranged that the engineer can tell at a glance the condition of the entire system.

The chimney of the power-house is about 750 feet from the center of the large dome, in a direction (north of east) from which the wind very rarely blows. Up to the present time the small amount of smoke emitted by it has not given the slightest inconvenience. In case it should do so the efficient smoke consumers attached to the boilers could be brought into service. It has been found that they will almost instantly reduce a heavy cloud of black smoke to a hardly visible vapor.

The steam-pipes for heating, electric cables for power and light, and the water pipes are led underground from the power-house to the Observatory. Mr. E. N. Myers is the engineer in charge of the heating and power plant.

YERKES OBSERVATORY,
April 1897.

(*To be continued.*)

AUTOMATIC PHOTOGRAPHY OF THE CORONA.

By DAVID P. TODD.

THE great variety of problems arising in the photography of the corona and its spectrum, and yet unsolved, led to the equipment of the Amherst Eclipse Expedition to Japan last year with a type of apparatus essentially novel. The uncertainty of clear August skies in the Hokkaido also contributed to this decision; for should totality be cloudy, as unfortunately proved to be the case, the expedition might still bring back results of much significance in further eclipse work, provided the practicability of operating a large number of photographic instruments as an automaton could be demonstrated.

My attention was first called to this subject in 1878, on the return of the government expeditions to Washington. Excellent photographs had been obtained; but the number of instruments available for a manual routine and the number of photographs obtainable by hand-exposure struck me as exceedingly meager for an occasion when, like a total eclipse of the Sun, the money value of a single second is often hundreds of dollars. And this would still be true even if the human mechanism remained unperturbed under the strain and tension of totality; but sad experience shows its frailty, as attested by numerous and unfortunate instances of slips in the execution of a perfectly arranged programme, no matter how constantly rehearsed.

Then, too, the few exposures with any given instrument ordinarily precludes the chance of experimenting in the development of the negative. If a single series of exposures is obtained, representing a complete range in time, and one of these is developed too far, it is extremely desirable to have at hand an exact duplicate as to instrument and exposure; for the error of judgment may then be corrected. Also the detailed study of characteristic coronal forms has so far been greatly

hampered by the lack of sufficiently large numbers of original negatives for distribution among prominent students of solar physics; even the best transfer from a negative of the corona rarely shows everything that the original does. Our only present available method is to secure originals in sufficient abundance for extended distribution. This demands a great reduction of the time ordinarily lost in changing plates by hand; and the work of our expedition has proved, notwithstanding the clouds, that all the conditions can be amply met by the ease, precision and certainty of well-devised and carefully constructed mechanical movements.

Besides all this there is a wide range of questions not yet solved, for the testimony of past eclipses is by no means uniform: whether small instruments may not be equally effective with large ones; whether reflectors are superior to refractors; the proper sort of instrument to depict the faint outlying streamers, and the more important question of exposure suitable for them; whether the wet process may not be superior to the dry; whether orthochromatic screens should be used, and of what shade; how may the very bright inner and the excessively faint outer coronas be photographed on a single plate; and so on. Naturally we get some light on these questions from exposures upon the Moon and other objects, but the conditions of an eclipse are so divergent from the ordinary that, in the present state of coronal photography, they necessitate relative experiment with different instruments and processes side by side, and upon the corona itself.

The operation of twenty or thirty instruments by hand is out of the question, even if human nerves were infallible. To accomplish the desired end by mechanical devices three systems are feasible:

(*a*) All the mechanical movements may be effected by levers and cords and pulleys directly connected. This system was first worked out in crude form, with the contrivances at our disposal, at the eclipse station in Shirakawa, Japan, in August 1887. P. A. Engineer John Pemberton, U. S. Navy, rendered

very great assistance in the practical details. Our instruments were not of a type to lend themselves very handily to these constructions, but the lever system proved very practical and positive although cumbersome and limited in its application.

(*b*) Prior to the expedition to West Africa under my charge, for the eclipse of the 22d December 1889, a complete pneumatic system of automatic instruments had been worked out and constructed with the assistance of Professor Bigelow. Then it was demonstrated for the first time practicable for a few observers to take a very large quantity of specialized apparatus into the field, mount and adjust it, expose the plates, develop and return them to fellow investigators for whom the time and fatigue of long journeys could be spared. But most unfortunately an accident of the day in the shape of an untimely cloud precluded totality-pictures, although the multitude of novel photographic devices proved itself fully competent to the task marked out for it.

(*c*) It was not any uncertainty in the working of the pneumatic system which led to its abandonment last summer for the trial of the third or electric system of control, but rather the greater convenience in leading wires than pipes, not to say also the greater simplicity of construction and operation of the electric commutator, as described farther on. Extended experience with all three systems has convinced me that this last is decidedly the best; and it has shown itself perfectly competent to operate any available number of eclipse instruments whose record can be obtained photographically. Not only does it accomplish this accurately and positively, but it likewise makes the time-record of every automatic movement in identifiable form.

Early in the autumn of 1895 Mr. D. Willis James, a trustee of Amherst College, and his son, Arthur Curtiss James, a graduate, generously tendered the use of their splendid schooner yacht, "The Coronet," to convey an expedition to Japan for observing the total eclipse of the Sun. In August last year Mr. Pemberton was again one of my faithful coadjutors, by the

courteous permission of the Secretary of the Navy; Professor Pickering, of the Harvard Observatory, kindly gave Mr. Gerrish, well-known for his ready skill in astronomical devices and constructions, leave to accompany us; Mr. E. A. Thompson, a practical and inventive expert, was engaged as chief constructing mechanician, and our instruments were in large part built by him and his sons Herbert and Frank; and in Japan a highly skillful artist, Mr. K. Ogawa, and his assistants, were engaged for the purpose of carrying out our abundant photographic plans. Both the wet process and the dry were employed.

As in the African expedition seven years previously, the instruments were provided by the kind coöperation of many individuals and institutions, to whom full credit is given in the report of our expedition. In all twenty photographic instruments were worked into the automatic system, and complete preparations were made which, but for an unhappy repetition of our experience in West Africa, would have given us more than four hundred exposures with several types of reflecting and refracting telescopes, photographic doublets, a pair of spectroscopes, photometers, and a pair of polariscopes.

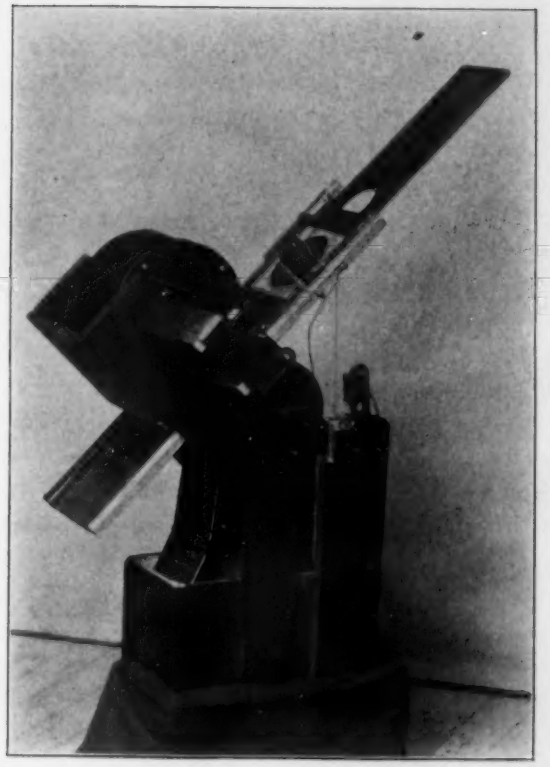
The precision of working of all this complicated system of apparatus has thoroughly convinced me of its absolute practicability. I am satisfied, too, that the mechanical principles involved have been thought out and experimented upon with such care and completeness that the detailed constructions may now be published for the benefit of others who, like myself, are convinced that the infrequent availability of eclipses renders it incumbent upon us to extend the duration of totality from three minutes to thirty on every possible opportunity.

Pending the fuller publication in the report of our expedition, in which all the constructions and devices are given with working drawings, I have pleasure in presenting to the readers of the ASTROPHYSICAL JOURNAL, by the courtesy of Professor Hale, the following description of one type of automatic movement which we found most practicable, together with a descrip-

tion of the electric commutator, by which the circuits of all the instruments were unerringly controlled.

Numerous devices for experimental shutters have been tried, but the type found best adapted to quick automatic control is a hollow rotary cylinder with a clear space cut through it, as shown in Plate XXIII (upper left-hand side). Alternate quarter turns open and close it, and the rotation is under the precise, speedy, and effective control of an electric escapement permitting only a single quarter turn at each closing of the circuit. Below it and to the right is shown the plate movement. It is a four-sided barrel, whose revolution is effected by a long and powerful spiral spring wound round its journal. The "fly" of a striker movement in an ordinary clock is connected with a pulley on the axis of the plate-barrel, and serves to make its working positive and yet not too rapid. This device is perhaps the best of our constructions; it keeps abundant power in proper check, and the detent-pins on the face of the barrel stop without any jar on meeting the escapement-pallets. Freedom from jar is a fundamental essential in all the automatic movements when several instruments are mounted on the same polar axis; for the tremor of the shutter and plate movement of one might ruin the definition of another where an exposure is in progress. The plates are slipped into holders strung together in a jointed but inextensible chain, which passes over the four-sided plate drum. A long chain of plates of any desired size is easily within the capacity of this construction. The heaviest loads thrown upon instruments of this type were a chain of 24 plates 8×10 inches, and 150 plates 2×2½ inches. Both showed themselves capable of perfect working. The particular movement shown in the illustration handled 36 plates 4×5 inches. The large diagonal slide was constructed for automatic working by an armature as figured on its right side, gravity furnishing the power; and two orthochromatic screens, one orange and the other neutral tint, were mounted in the two apertures, and permitted to descend between barrel and shutter at the instant required. At first the plate drum and shutter were both moved independently by cir-

PLATE XXIII.



TYPE OF AUTOMATIC SHUTTER WITH PLATE MOVEMENT.

cuits from the commutator; but in our final instruments a contact spring was attached to each shutter, and an independent circuit through it controlled the shifting of the plates.

The basis of the commutator is an old chronograph with a ten-inch cylinder. Its movement was reconstructed so as to eliminate all backlash. At the right-hand end of the barrel is a coarse feed screw, and held rigidly in gear with it by a spring is a half-nut attached to the bent arm leading upward to the sliding-board to which the contact comb is secured. The number of contact springs, or teeth of this comb, is forty-eight. The barrel revolves, like that of an ordinary chronograph, once in sixty seconds. As totality was not to exceed three minutes, the contact springs, or teeth of the comb, were placed at a distance apart equal to three threads of the feed-screw. The barrel, originally of wood, was replaced by hard-rubber ends and a periphery of thin sheets of planished copper. Small brass contact pins were secured to the cylinder wherever a contact was required by boring into the copper sheets and tapping. The pins were then screwed in firmly against a small shoulder on each, affording rigidity and perfect contact with the copper. To facilitate placing them the barrel was mounted in a lathe and a delicate spiral traced over its entire length, using the same feed employed in cutting the feed-screw for the contact comb. Exact correspondence was thus secured. At ten-second intervals fine longitudinal lines were drawn across the barrel, and the number of each tenth-second, continuously from 0 to 8640, was engraved at the point of its intersection with the spiral. By this simple device it was possible to locate the position of each pin in a few seconds, and to verify it from the complete index of contacts. This was carefully calculated in advance, and embodied the full scheme of automatic movements for each instrument. As the number of independent circuits was forty-eight, all capable of operation by the commutator for 180 seconds, and any pin could be placed with accuracy to $\frac{1}{20}$ of a second, the ultimate capacity of the instrument is expressed by the product of these, or rather more than 170,000. Above the commutator is shown the

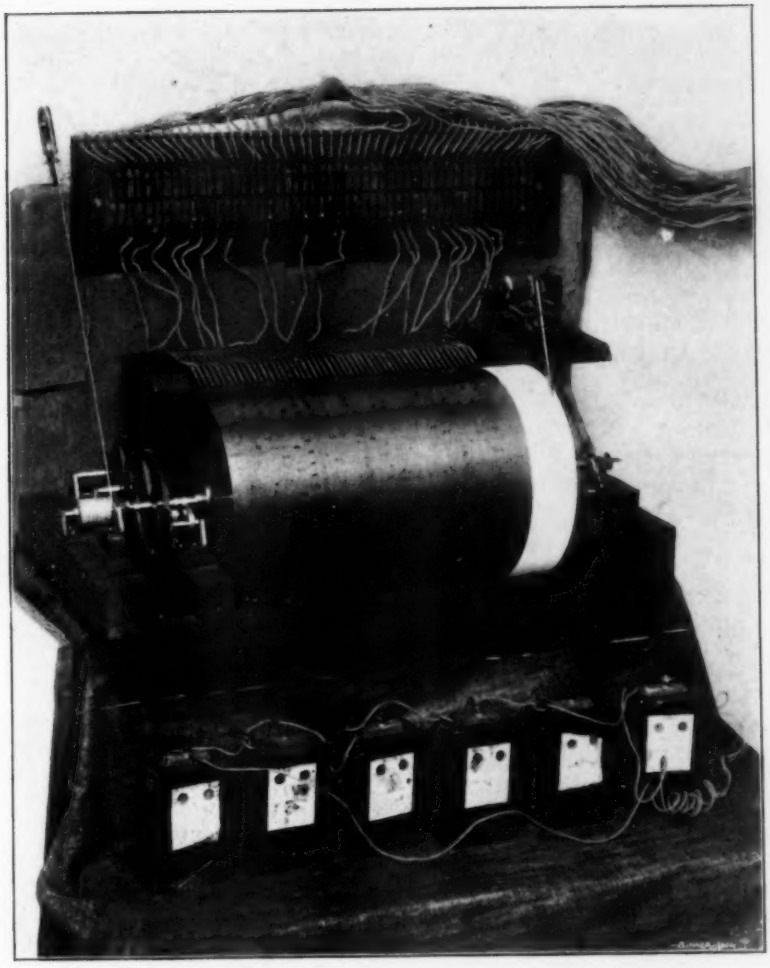
switchboard, by means of which any desired combination of instruments might be effected. It was especially useful in the preliminary experiments. The current was furnished by twelve Edison-Lalande cells of type *S* (not shown) reinforced by six dry batteries of an excellent form manufactured in Tōkyō. A fillet wound round the end of the commutator barrel recorded its running by means of a pen and clock circuit in the usual manner. Thereby the commutator performed the double duty, not only of making the exposures themselves, but of recording with precision the beginning and end of each.

Among other instruments designed and constructed by the expedition, to operate automatically by the commutator, was one which, it is hoped, may assist in the difficult task of photographing both the bright inner and the faint outer coronas on a single plate. Some, then, at least of the complex filaments may be studied throughout their entire length. At the beginning of exposure, three concentric rings and one central disk intercept all rays from the corona, except those of the outlying streamers. In proper succession the rings, followed by the disk, rise automatically, and quickly remove from the photographic field, thereby allowing a differential exposure of the inner corona in rings. As the time of exposure of each ring is controlled by the pins in the commutator barrel, it is expected that practically the whole of the corona, both outer and inner, may be correctly timed on a single plate. Six plates gave a chance to vary the relative exposure in the different rings. But this rather intricate instrument, although its mechanical movements were perfect, suffered a like fate with the others; and it will be interesting to see what it may be competent to do on future occasions.

Of all our apparatus, however, this may be said, that it is provisionally constructed as yet; and it is hoped to try it again during the eclipse of either 1898 or 1900. Both of these are of short duration, only about two minutes, and are to be regarded simply as tentative rehearsals for the great totality of six minutes, in Sumatra, on the 18th of May, 1901.

AMHERST COLLEGE OBSERVATORY,
April 1897.

PLATE XXIV.



ELECTRIC COMMUTATOR OF THE AMHERST ECLIPSE EXPEDITION.

A METHOD OF CORRECTING THE CURVATURE OF LINES IN THE SPECTROHELIOGRAPH.

By W. H. WRIGHT.

THE question of the curvature of lines in the prismatic spectrum has been discussed from time to time, and methods of more or less theoretical validity have been proposed for its correction. Professor Stokes investigated the form of a compound prism giving straight lines, and such prisms have been constructed. In 1874 Mr. Thomas Grubb[1] suggested correction by means of a curved slit. These are so far as the writer knows the only successful methods that have been proposed. By shortening the slit, however, the effects of curvature can be reduced to a minimum and the resulting lines, when magnified, are sensibly straight. But in the case of the spectroheliograph, where a long slit is usually desirable, the curvature becomes noticeable when even moderate dispersion is used, and must be allowed for in the measurement of solar negatives; it would therefore seem desirable to eliminate this distortion if possible. I am unable to learn anything regarding the efficiency of the compound prisms mentioned above, and the plan proposed by Grubb is evidently not applicable to the spectroheliograph. In this instrument, however, only a small part of the spectrum is used at a time, and the peculiar conditions allow special methods.

Before proceeding with the discussion it may be well to call attention to a point involved in the design of that form of spectroheliograph in which the slits are stationary with regard to the prism train, and the Sun and photographic plate move. Let S' (Fig. 1) be the first slit of the instrument and S'' its image on the second slit; further let the side a'' be the image of a', and b'' of b'. Suppose now the Sun's image is caused to move over S' from a' to b'. It is evident from the most elementary considerations that the photographic plate should move from a'' to b'', other-

[1] *Proc. R. Soc.* **22**, 308.

wise the image of a point, say in a prominence, would be drawn out into a line on the plate. This line would be perpendicular to the slit, and twice as long as the slit is broad. The resultant blurring would then be a function of the width of the slit, and the maximum width of slit allowable with a system of this sort could be determined from the resolving power of the lens, the grain of the photographic plate, and the efficiency of the instrument. But an inspection of some of the prominence pictures taken at the Kenwood Observatory shows a wealth of detail which demands that every precaution be taken against blurring in future designing of the spectroheliograph. This point is very simple; it is liable to escape attention however, and affects one of the forms of instrument suggested by Mr. Newall.[1]

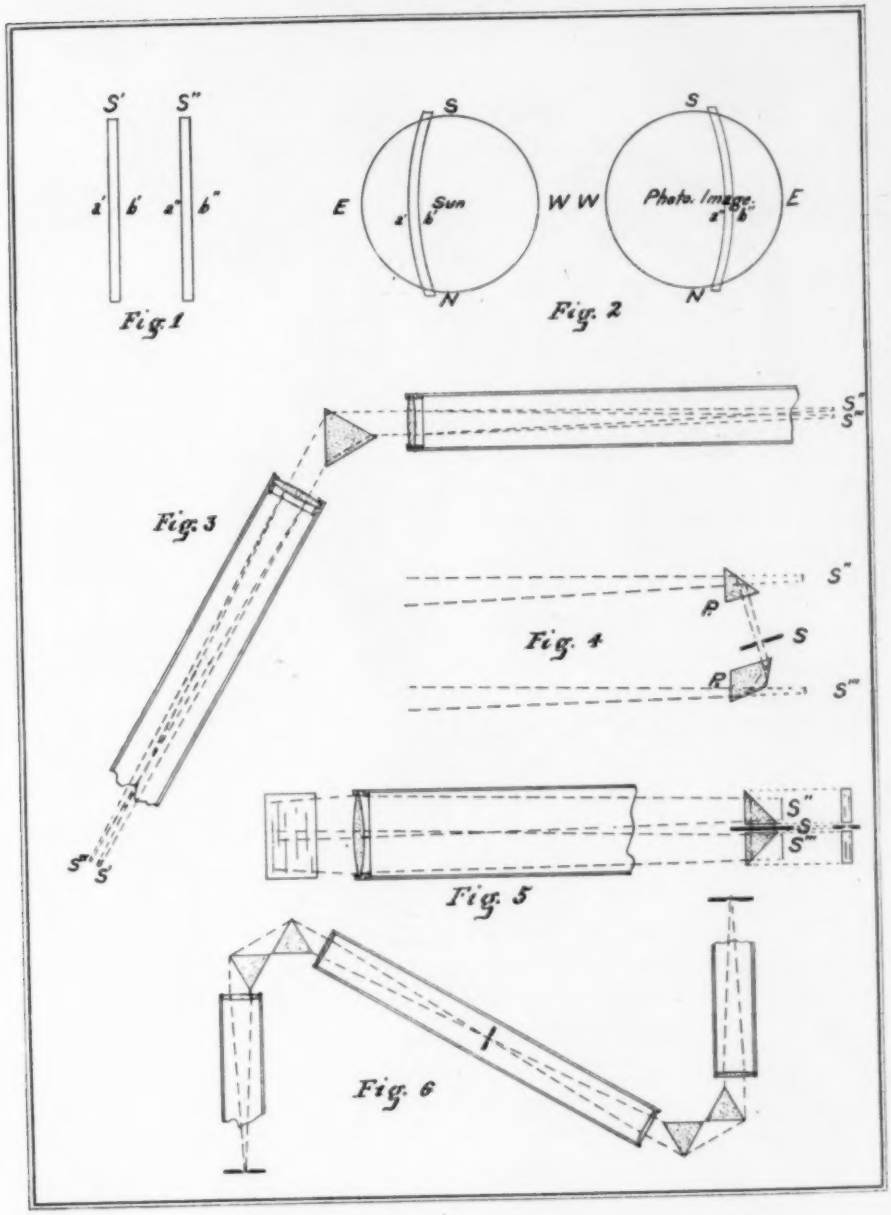
If the slits are so narrow that this astigmatism may be neglected, the distortion due to curvature may be eliminated by the following method suggested by Professor Wadsworth. The front slit is curved so as to be convex toward the edges of the prism (Fig. 2). This will flatten out the image at S'', and the curvature of S' may be so figured that S' and S'' are similar. Now if the Sun travels over S' in the direction $a'\ b'$ and the plate behind S'' in the direction $b''\ a''$, the slit curvature will be entirely corrected. The resulting negative, however, will be *reversed* when compared with an ordinary one.

The following form of instrument is mentioned with an appreciation of some of its objectionable features, among others its Littrow form, the reflections involved, and the additional absorption attendant upon the return of the light through the prisms. However, it possibly has some advantages to be indicated later and is submitted for what it may be worth.

As before let S' (Fig. 3) be the first slit, and S'' the second. By placing a mirror at S'', we could form an image of S'' at S', *i. e.*, an image of S' on itself. This image would be corrected for curvature due to prisms, and in addition to any distortions due to motions in the line of sight, and haziness caused by non-monochromatism of the light used. However, in this position

[1] *Proc. Camb. Phil. Soc.*, 9, 179.

PLATE XXV.



A METHOD OF CORRECTING THE CURVATURE OF LINES IN THE SPECTROHELIOGRAPH.

our image would avail us little. But by moving S'' to S''' we could form an image S^{iv}, which could be made to satisfy these conditions to within quantities of a negligible order by properly adjusting the line of minimum deviation within the angle $S''\,L''\,S'''$.[1] The shifting of S'' to S''' may be accomplished by reflection from an odd number of mirrors, as in Fig. 4, in which P_1 and P_2 are reflecting prisms, and S a slit, curved to admit the line desired. Instead of moving S'' to S''' we might move it directly down (perpendicular to the paper) by means of the arrangement shown in Fig. 5. This would eliminate one reflection, and would be theoretically perfect, but would necessitate longer prisms, and correspondingly larger lenses. Reflecting prisms might be introduced at S' and S^{iv} as suggested by Mr. Newall, or some other device might be adopted.

As indicated above, this instrument should correct blurring due to hazy lines, and distortions due to line-of-sight motions, when the slit may be opened wide enough to admit the whole of the distorted line. By the use of practically two spectroscopes, as indicated in Fig. 6, the principal objections to the above forms might be disposed of. This whole instrument, it will be noticed, would move in the plane of the paper, the solar image and the photographic plate remaining stationary, as in the spectroheliograph designed by Professor Hale for the late Mr. Raynard. It seems extremely doubtful however, whether the apparent advantages of such a construction would warrant the additional expense and complication.

It will be noticed that the function of the above apparatus is essentially that of a color screen, analogous in some respects to the instrument devised by Professor Wadsworth for cutting out overlapping spectra from a grating spectroscope, and described in this JOURNAL, **3**, 169–191.

YERKES OBSERVATORY,
April 1897.

[1] The indulgence of the reader is requested in reference to two oversights in the draughting of the accompanying plate. The first is the omission of the letter L′ designating the optical center of the second lens (Fig. 3), the second that of a reversing prism in Fig. 6 between the second slit and the second collimator.

SPECTROGRAPHIC OBSERVATIONS OF MARS IN 1896–7.

By JAMES E. KEELER.

THE question whether it is possible to detect the existence of water vapor in the atmosphere of Mars by means of the spectroscope has been the subject of considerable discussion in the last few years. Professor Campbell,[1] as a result of observations made with powerful apparatus under the most favorable conditions, has come to the conclusion that it is not. Mr. Jewell[2] has arrived at the same conclusion from considerations based on his studies of the telluric lines in the solar spectrum at Baltimore, and dismisses the question as one which lies far beyond our means of investigation. Even if it were possible to observe the planet with the apparatus he used for the Sun, the sensitiveness of the method would be insufficient for the purpose. On the other hand, a slight strengthening of the telluric bands in the spectrum of Mars relatively to that of the equally high Moon has been noted by skillful observers on a number of occasions. The extreme difficulty of these observations must not, however, be forgotten.

With regard to the best form of apparatus for such observations there has been some difference of opinion. Mr. Jewell holds that a high resolving power is necessary, while Mr. Campbell considers that high resolving power is not necessary or even desirable. My own experiments[3] lead me to agree with the views of Mr. Campbell. They relate, however, merely to the best means of observation. So far as the main question is concerned, it seems to me that the reasoning which Mr. Jewell applies to the case of an isolated water-vapor line is equally applicable to the lines taken collectively.

[1] *Pub. A. S. P.*, **6**, 228. *Ap. J.*, **2**, 28.
[2] *Ap. J.*, **3**, 255.
[3] *Ap. J.*, **4**, 137.

During the winter of 1896–7 I made some experiments in this direction by photographing the spectra of Mars and the Moon on the same plate. The advantages of the method are obvious. Faintness of light can be compensated for by prolonged exposure; the spectra of the two bodies can be given practically equal width and density ; they are brought into juxtaposition, so that the comparison is made with the greatest ease and certainty, and a permanent record is secured, which can be consulted as often as desired. On the other hand there are some disadvantages, the chief of which is the great variation of the sensitiveness of the plate with the wave-length in the region where the water-vapor lines occur, while the delicacy of the method, as compared with that of visual observations, is open to doubt Aside from these disadvantages, the precise weight of which could only be ascertained by experiment, there was the very unfavorable condition that the atmosphere at Allegheny almost always contains a large amount of moisture. This, however, equally affects visual observations, and is not to be avoided, especially since the circumstances permit little range in the choice of nights.

The instrument used for the comparison was the Thaw spectroscope[1] mounted on the 13-inch equatorial. The collimator and the camera have each a focal length of 16 inches and an effective aperture of 1.12 inches. A single dense prism was used. It was my intention to use also the train of three prisms, but unfortunately the number of suitable nights was so small that this part of the programme could not be carried out.

Satisfactory photographs were obtained on the nights of December 13 and 16, 1896, and February 13, 1897, when the sky was what passes for clear in Allegheny. The ratio of exposure-times required to produce equal density at the D lines was determined on each evening by a preliminary experiment. On December 16 the exposures were: Moon 16^m, Mars 27^m. Both bodies were at a high altitude. The temperature was 27° and the relative humidity 77 per cent. Several plates were

[1] *A. and A.*, **12**, 40.

obtained, on which the spectra of the Moon and Mars were almost exactly equal in width and density. On February 13 the disk of Mars had become so small that it was allowed to drift its own width along the slit, and the exposure was correspondingly increased.

The spectra obtained in the manner described above extend to some distance below the D lines (which are well separated on the plates), and therefore include the water-vapor band in this region, as well as the δ band farther above. But in order to show satisfactorily this extent of spectrum, at a place where the sensitiveness of an orthochromatic plate varies so rapidly with the wave-length, it was necessary to give very full exposure; and therein lies a weakness of the method, for the equalization of density produced by the full exposure also diminishes the contrast between the atmospheric band and the background of continuous spectrum. As a matter of fact, no difference whatever could be found between the spectra of the Moon and Mars, when both bodies were at a high altitude, on any of the plates, and the results of the observations being negative, I have not considered it worth while to describe them in greater detail.

In order to obtain some data for estimating the sensitiveness of the method, comparisons were made in the same way of the high and low Sun, and of the Moon near the zenith and at various lower altitudes. It was found from these comparisons that no differences in the spectra could be detected until the zenith distance of the body at the lower observation was something like 45° or 50°. A slight increase in the strength of the atmospheric bands was suspected at about this point; a decided increase took place only at a much greater zenith distance. It appears therefore that the additional effect of half such an atmosphere as the Earth's might possibly be detected by the method employed. There is every reason to suppose that no effect so great as this can be produced by the atmosphere of Mars.

These results, as far as they go, agree with those obtained visually by Mr. Campbell. I would not, however, draw any

sweeping conclusions from them, since it is quite possible that if a different dispersion had been employed, or even if the plates had been exposed or developed differently, the effectiveness of the method might have been increased.

Such observations evidently require a more favorable climate than that of the eastern United States. It seems to me that Mr. Campbell is justified in attaching great weight to the superior conditions under which his observations were made, *i. e.*, to the dryness of the air at Mt. Hamilton and the elevation of the Observatory above sea level, and also to the observation of the relative strength of the water-vapor lines in the spectrum of Mars at different parts of the disk. A glance at Mr. Jewell's diagram [1] shows that a considerable strengthening of the lines can be expected only at points very near the limb, and hence a large image, obtainable, without sacrifice of light, only with a large telescope, is required. The possibility of making satisfactory comparisons with such an instrument under the best circumstances could probably be correctly estimated only by one actually looking at the spectrum. Personally, I believe this test to be far more reliable than any other that has been proposed.

[1] *Ap. J.*, 1, 314.

ON THE INFLUENCE OF MAGNETISM ON THE NATURE OF THE LIGHT EMITTED BY A SUBSTANCE.[1]

By P. ZEEMAN.

1. SEVERAL years ago, in the course of my measurements concerning the Kerr phenomenon, it occurred to me whether the light of a flame if submitted to the action of magnetism would perhaps undergo any change. The train of reasoning by which I attempted to illustrate to myself the possibility of this is of minor importance at present;[2] at any rate I was induced thereby to try the experiment. With an extemporized apparatus the spectrum of a flame, colored with sodium, placed between the poles of a Ruhmkorff electro-magnet, was looked at. The result was negative. Probably I should not have tried this experiment again so soon had not my attention been drawn some two years ago to the following quotation from Maxwell's sketch of Faraday's life. Here (Maxwell, *Collected Works*, II, 790) we read: "Before we describe this result we may mention that in 1862 he made the relation between magnetism and light the subject of his very last experimental work. He endeavored, but in vain, to detect any change in the lines of the spectrum of a flame when the flame was acted on by a powerful magnet." If a Faraday[3] thought of the possibility of the above-mentioned relation, perhaps it might be yet worth while to try the experiment again with the excellent auxiliaries of spectroscopy of the present time, as I am not aware that it has been done by others.[4] I will take the liberty of stating briefly to the readers of the *Philosophical Magazine* the results I have obtained up till now.

2. The electro-magnet used was one made by Ruhmkorff and

[1] *Philosophical Magazine* [5], **43**, March 1897, p. 226.

[2] *Cf.* §§ 15 and 16.

[3] See appendix for Faraday's own description of the experiment.

[4] See appendix.

of medium size. The magnetizing current furnished by accumulators was in most of the cases 27 amperes, and could be raised to 35 amperes. The light used was analyzed by a Rowland grating, with a radius of 10 feet and with 14,938 lines per inch. The first spectrum was used, and observed with a micrometer eyepiece with a vertical cross-wire. An accurately adjustable slit is placed near the source of light under the influence of magnetism.

3. Between the paraboloidal poles of an electro-magnet the middle part of the flame from a Bunsen burner was placed. A piece of asbestos impregnated with common salt was put in the flame in such a manner that the two D lines were seen as narrow and sharply defined lines on the dark ground. The distance between the poles was about 7^{mm}. If the current was put on, the two D lines were distinctly widened. If the current was cut off they returned to their original position. The appearing and disappearing of the widening was simultaneous with the putting on and off of the current. The experiment could be repeated an indefinite number of times.

4. The flame of the Bunsen was next interchanged with a flame of coal gas fed with oxygen. In the same manner as in § 3 asbestos soaked with common salt was introduced into the flame. It ascended vertically between the poles. If the current was put on again the D lines were widened, becoming perhaps three or four times their former width.

5. With the red lines of lithium, used as carbonate, wholly analogous phenomena were observed.

6. Possibly the observed phenomena (§§ 3, 4, 5) will be regarded as nothing of any consequence. One may reason in this manner: widening of the lines of the spectrum of an incandescent vapor is caused by increasing the density of the radiating substance and by increasing the temperature.[1] Now, under the influence of the magnet, the outline of the flame is undoubtedly changed (as is easily seen), hence the temperature and possibly also the density of the vapor is changed. Hence one

[1] *Cf.* however, also Pringsheim (*Wied. Ann.*, **45**, 457, 1892).

might be inclined to account in this manner for the phenomenon.

7. Another experiment is not so easily explained. A tube of porcelain, glazed inside and outside, is placed horizontally between the poles with its axis perpendicular to the line joining the poles. The inner diameter of the tube is 18^{mm}, the outer one 22^{mm}. The length of the tube is 15^{cm}. Caps are screwed on at each end of the tube;[1] these caps are closed by plates of parallel glass at one end and are surrounded by little water-jackets. In this manner, by means of a current of water, the copper caps and the glass plates may be kept sufficiently cool while the porcelain tube is rendered incandescent. In the neighborhood of the glass plates, side tubes provided with taps are fastened to the copper caps. With a large Bunsen burner the tube could be made incandescent over a length of 8^{cm}. The light of an electric lamp, placed sideways at about two meters from the electro-magnet, in order to avoid disturbing action on the arc, was made to pass through the tube by means of a metallic mirror. The spectrum of the arc was formed by means of the grating. With the eyepiece the D lines are focused. This may be done very accurately, as in the center of the bright D lines the narrow reversed lines are often seen. Now a piece of sodium was introduced into the tube. The Bunsen flame is ignited and the temperature begins to rise. A colored vapor soon begins to fill the tube, being at first of a violet, then of a blue and green color, and at last quite invisible to the naked eye. The absorption soon diminishes as the temperature is increased. The absorption is especially great in the neighborhood of the D lines. At last the two dark D lines are visible. At this moment the poles of the electro-magnet are pushed close to the tube, their distance now being about 24^{mm}. The absorption lines now are rather sharp over the greater part of their length. At the top they are thicker, where the spectrum of the lower, denser vapors was observed. Immediately after

[1] PRINGSHEIM uses similar tubes in his investigation concerning the radiation of gases, *l. c.*, p. 430.

the closing of the current the lines *widen* and are seemingly *blacker;* if the current is cut off they immediately recover their initial sharpness. The experiment could be repeated several times, till all the sodium had disappeared. The disappearance of the sodium is chiefly to be attributed to the chemical action between it and the glazing of the tube. For further experiments, therefore, unglazed tubes were used.

8. One may perhaps try to account for the last experiment (§ 7) in this direction: it is true that the tube used was not of the same temperature at the top and at the bottom; further, it appears from the shape of the D lines (§ 7) that the density of the vapor of sodium is different at different heights. Hence certainly convection currents caused by difference of temperature between the top and bottom were present. Under certain plausible suppositions one may calculate that, by the putting on of the electro-magnet, differences of pressure are originated in the tube of the same order of magnitude as those caused by the difference of temperature. Hence the magnetization will push *e. g.*, the denser layer at the bottom in the direction of the axis of the tube. The lines become widened. For their width at a given height is chiefly determined by the number of incandescent particles at that height in the direction of the axis of the tube. Although this explanation still leaves some difficulties, certainly something may be said for it.

9. The explanation of the widening of the lines attempted in § 8 is no longer applicable to the following variation of the experiment, in which an unglazed tube is used. The inner diameter of the tube, about 1^{mm} thick, was 10^{mm}. The poles of the electro-magnet could be moved till the distance was 14^{mm}. The tube was now heated by means of the blowpipe instead of with the Bunsen burner, and became in the middle part white hot. The blowpipe and the smaller diameter of the tube make it easier to bring the upper and lower parts to the same temperature. This is now higher than before (§ 7) and the sodium lines remain visible continuously.[1] One can now wait till the

[1] PRINGSHEIM, *l. c.*, p. 456.

density of the sodium vapor is the same at various heights. By rotating the tube continuously round its axis I have still further promoted this. The absorption lines now are equally broad from the top to the bottom. When the electro-magnet was put on, the absorption lines immediately widened along their whole length. Now the explanation in the manner of § 8 fails.

10. I should like to have studied the influence of magnetism on the spectrum of a solid. Oxide of erbium has, as was found by Bunsen or Bahr, the remarkable property of giving by incandescence a spectrum with bright lines. With the dispersion used, however, the edges of these lines were too indistinct to serve my purpose.

11. The different experiments from §§ 3 to 9 make it more and more probable that the absorption—and hence also the emission lines of an incandescent vapor are widened by the action of magnetism. Now if this is really the case, then by the action of magnetism on the free vibrations of the atoms, which are the cause of the line spectrum, other vibrations of changed period must be superposed. That it is really inevitable to admit this specific action of magnetism is proved, I think, by the rest of the present paper.

12. From the representation I had formed to myself of the nature of the forces acting in the magnetic field on the atoms, it seemed to me to follow that with a band spectrum and with external magnetic forces the phenomenon I had found with a line spectrum would not occur.

It is, however, very probable that the difference between a band and a line spectrum is not of a quantitative but of a qualitative kind.[1] In the case of a band spectrum the molecules are complicated; in the case of a line spectrum the widely separated molecules contain but a few atoms. Further investigation has shown that the representation I had formed of the cause of the widening in the case of a line spectrum in the main was really true.

13. A glass tube, closed at both ends by glass plates with

[1] KAYSER in Winklemann's *Handbuch*, II, 1, p. 421.

parallel faces and containing a piece of iodine, was placed between the poles of the Ruhmkorff electro-magnet in the same manner as the tube of porcelain in § 7. A small flame under the tube vaporized the iodine, the violet vapor filling the tube.

By means of electric light the absorption spectrum could be examined. As the temperature is low this is the band spectrum. With the high dispersion used, there are seen in the bands a very great number of fine dark lines. If the current around the magnet is closed, *no* change in the dark lines is observed, which is contrary to the result of the experiments with sodium vapor.

The absence of the phenomenon in this case supports the explanation, that even in the first experiment, with sodium vapor (§7) the convection currents had no influence. For in the case now considered, the convection currents originated by magnetism, which I believed to be possible in that case, apparently are insufficient to cause a change of the spectrum; yet, though I could not see it in the appearance of the absorption lines (*cf.* § 7), the band spectrum is, like the line spectrum, very sensible to changes of density and of temperature.

14. Although the means at my disposal did not enable me to execute more than a preliminary approximate measurement, I yet thought it of importance to determine approximately the value of the magnetic change of the period.

The widening of the sodium lines to both sides amounted to about $\frac{1}{40}$ of the distance between the said lines, the intensity of the magnetic field being about 10^4 C. G. S. units. Hence follows a positive and negative magnetic change of $\frac{1}{40000}$ of the period.

15. The train of reasoning mentioned in (1), by which I was induced to search after an influence of magnetism, was at first the following: If the hypothesis is true that in a magnetic field a rotary motion of the ether is going on, the axis of rotation being in the direction of the magnetic forces (Kelvin and Maxwell), and if the radiation of light may be imagined as caused by the motion of the atoms, relative to the center of mass of the molecule, revolving in all kinds of orbits, suppose for simplicity, circles; then the period, or what comes to the same, the

time of describing the circumference of these circles, will be determined by the forces acting between the atoms, and then deviations of the period to both sides will occur through the influence of the perturbing forces between ether and atoms. The sign of the deviation, of course, will be determined by the direction of motion, as seen from along the lines of force. The deviation will be the greater the nearer the plane of the circle approximates to a position perpendicular to the lines of force.

16. Somewhat later I elucidated the subject by representing to myself the influence exercised on the period of a vibrating system if this is linked together with another in rapid rotary motion. Lord Kelvin (now forty years ago)[1] gave the solution of the following problem: Let the two ends of a cord of any length be attached to two points at the ends of a horizontal arm made to rotate round a vertical axis through its middle point at a constant angular velocity, and let a second cord bearing a material point be attached to the middle of the first cord. The motion now is investigated in the case when the point is infinitely little disturbed from its position of equilibrium. With great angular velocity the solution becomes rather simple. Circular vibrations of the point in contrary directions have slightly different periods. If for the double pendulum we substitute a luminiferous atom, and for the rotating arm the rotational motion about the magnetic lines of force, the relation of the mechanical problem to our case will be clear.

It need not be proved that the above-mentioned considerations are at most of any value as indications of somewhat analogous cases. I communicate them, however, because they were the first motive of my experiments.

17. A real explanation of the magnetic change of the period seemed to me to follow from Professor Lorentz's theory.[2]

In this theory it is assumed that in all bodies small electri-

[1] *Proc. R. Soc.*, 1856.

[2] LORENTZ, *La Théorie électromagnétique de Maxwell.* Leyde, 1892; and *Versuch einer Theorie der electrischen und optischen Erscheinungen in bewegten Körpern.* Leyden, 1895.

cally charged particles with a definite mass are present, that all electric phenomena are dependent upon the configuration and motion of these "ions," and that light vibrations are vibrations of these ions. Then the charge, configuration, and motion of the ions completely determine the state of the ether. The said ion, moving in a magnetic field, experiences mechanical forces of the kind above mentioned, and these must explain the variation of the period. Professor Lorentz, to whom I communicated these considerations, at once kindly informed me of the manner in which, according to his theory, the motion of an ion in a magnetic field is to be calculated, and pointed out to me that, if the explanation following from his theory be true, the edges of the lines of the spectrum ought to be circularly polarized. The amount of widening might then be used to determine the ratio between charge and mass, to be attributed in this theory to a particle giving out the vibrations of light.

The above-mentioned extremely remarkable conclusion of Professor Lorentz relating to the state of polarization in the magnetically widened lines I have found to be fully confirmed by experiment (§ 20).

18. We shall now proceed to establish the equations of motion of a vibrating ion, when it is moving in the plane of (x, y) in a uniform magnetic field in which the magnetic force is everywhere parallel to the axis of z and equal to H. The axes are chosen so that if x is drawn to the east, y to the north, z is upwards. Let e be the charge (in electro-magnetic measure) of the positively charged ion, m its mass. The equations of relative motion then are :

$$\left.\begin{aligned} m\frac{d^2x}{dt^2} &= -k^2x + eH\frac{dy}{dt} \\ m\frac{d^2y}{dt^2} &= -k^2y - eH\frac{dx}{dt} \end{aligned}\right\} \qquad (1)^1$$

The first term of the second member expresses the elastic force drawing back the ion to its position of equilibrium; the

[1] These equations are like those of the Foucault pendulum, and of course lead to similar results.

second term gives the mechanical force due to the magnetic field. They are satisfied by

$$\left.\begin{aligned} x &= \alpha e^{st} \\ y &= \beta e^{st} \end{aligned}\right\} \tag{2}$$

provided that

$$\left.\begin{aligned} m s^2 \alpha &= -k^2 \alpha + e H s \beta \\ m s^2 \beta &= -k^2 \beta - e H s \alpha \end{aligned}\right\} \tag{3}$$

where m, k, e are to be regarded as known quantities.

For us the period T is particularly interesting. If $H = 0$, it follows from (3) that

$$S = i \frac{k}{\sqrt{m}} = i \frac{2\pi}{T}$$

or

$$T = \frac{2\pi\sqrt{m}}{k}. \tag{4}$$

If H is not 0, it follows from (3) approximately that

$$S = i \frac{k}{\sqrt{m}} \left(1 \mp \frac{e H}{2 k \sqrt{m}}\right).$$

Putting T' for the period in this case, we have

$$T' = \frac{2\pi\sqrt{m}}{k} \left(1 \pm \frac{e H}{2 k \sqrt{m}}\right). \tag{5}$$

Hence the ratio of the change of period to the original period becomes

$$\frac{e H}{2 k \sqrt{m}} = \frac{e}{m} \cdot \frac{H T}{4\pi}. \tag{6}$$

A particular solution of (1) is that representing the motion of the ions in circles. If revolving in the positive direction (viz., in the direction of the hands of a watch for an observer standing at the side towards which the lines of force are running) the period is somewhat less than if revolving in the negative direction. The period in the first case is determined by the value of (5) with the minus sign, in the second with the plus.

The general solution of (1) shows that the ions describe, besides circles, also slowly rotating elliptical orbits. In the general case, the original motion of the ion having an arbitrary position in space, it is perfectly clear that the projection of the

motion in the plane of (x, y) has the same character. The motion resolved in the direction of the axis of z is a simple harmonic motion, independent of and not disturbing the one in the plane of (x, y), and hence one not influenced by the magnetic forces. Of course, the consideration of the motion of an ion now given is only to be regarded as the very first sketch of the theory of luminiferous motions.

19. Imagine an observer looking at a flame placed in a magnetic field in a direction such that the lines of force run towards or from him.

Let us suppose that the said observer could see the very ions of § 18 as they are revolving; then the following will be remarked: There are some ions moving in circles and hence emitting circularly polarized light; if the motion is round in the positive direction the period will, for instance, be longer than with no magnetic field; if in the negative direction, shorter. There will also be ions seemingly stationary and really moving parallel to the lines of force with unaltered period. In the third place there are ions which seem to move in rotating elliptical orbits.

If one desires to know the state of the ether originated by the moving ions one may use the following rule, deduced by Professor Lorentz from the general theory: Let us suppose that in a molecule an ion P, of which the position of equilibrium is P_0, has two or more motions *at the same time*, viz., let the vector P_0P always be obtained by adding the vectors P_0P which should occur in each of the component motions at that moment; then the state in the ether at a very great distance in comparison with P_0P will be obtained by superposing the states which would occur in the two cases taken separately.

Hence it follows in the first place that a circular motion of an ion gives circularly polarized light to points on the axis of the circle.

Further, one may choose instead of the above-considered elliptical orbits a resolution more suited to our purpose. One may resolve the motion of the ion, existing before the putting

on of the magnetic force, into a rectilinear harmonic motion parallel to the axis of z and two circular (right-handed and left-handed) motions in the plane of (x, y).

The first remains unchanged under the influence of the magnetic force, the periods of the last are changed.

By the action of the grating the vibrations originated by the motion of the ions are sorted according to the period, and hence the complete motion is broken up into three groups. The line will be a triplet. At any rate one may expect that the line of the spectrum will be wider than in the absence of the magnetic field, and that the edges will give out circularly-polarized light.[1]

20. A confirmation of the last conclusion may be certainly taken as a confirmation of the guiding idea of Professor Lorentz's theory. To decide this point by experiment, the electro-magnet of § 2, but now with pierced poles, was placed so that the axes of the holes were in the same straight line with the center of the grating. The sodium lines were observed with an eyepiece with a vertical cross-wire. Between the grating and the eyepiece were placed the quarter-undulation plate and Nicol which I formerly used in my investigation of the light normally reflected from a polarly magnetized iron mirror.[2]

The plate and the Nicol were placed relatively in such a manner that right-handed circularly polarized light was quenched. Now according to the preceding the widened line must at one edge be right-handed circularly polarized, at the other edge left-handed. By a rotation of the analyzer over 90° the light that was first extinguished will be transmitted, and *vice versa*. Or, if first the right edge of the line is visible in the apparatus, a reversal of the direction of the current makes the left edge visible. The cross-wire of the eyepiece was set in the bright line. At the reversal of the current the visible line moved! This experiment could be repeated any number of times.

[1] I saw afterward that Stoney, *Trans. R. Soc., Dublin*, IV, endeavors to explain the existence of doublets and triplets in a spectrum by the rotation of the elliptical orbits of the "electrons" under the influence of perturbing forces.

[2] ZEEMAN, *Communications of the Leyden Laboratory*, No. 15.

21. A small variation of the preceding experiment is the following: With unchanged position of the quarter-wave plate the analyzer is turned round. The widened line is then, during one revolution, twice wide and twice fine.

22. The electro-magnet was turned 90° in a horizontal plane from the position of § 20, the lines of force now being perpendicular to the line joining the slit with the grating. The edges of the widened line now appeared to be plane polarized, at least in so far as the present apparatus permitted to see, the plane of polarization being perpendicular to the line of the spectrum. This phenomenon is at once evident from the consideration § 19. The circular orbits of the ions being perpendicular to the lines of force are now seen on their edges.

23. The experiments 20 to 22 may be regarded as a proof that the light vibrations are caused by the motion of ions, as introduced by Professor Lorentz in his theory of electricity. From the measured widening (§ 14) by means of relation (6), the ratio $e : m$ may now be deduced. It thus appears that $e : m$ is of the order of magnitude 10^7 electro-magnetic C. G. S. units. Of course this result from theory is only to be considered as a first approximation.

24. It may be deduced from the experiment of § 20 whether the positive or the negative ion revolves.

If the lines of force were running towards the gratings, the right-handed circularly polarized rays appeared to have the smaller period. Hence in connection with § 18 it follows that the positive ions revolve, or at least describe the greater orbit.

25. Now that the magnetization of the lines of a spectrum can be interpreted in the light of the theory of Professor Lorentz, the further consideration of it becomes specially attractive. A series of further questions already present themselves. It seems very promising to investigate the motion of the ions for various substances, under varying circumstances of temperature and pressure, with varying intensities of the magnetization. Further inquiry must also decide as to how far the strong mag-

netic forces existing according to some at the surface of the Sun may change its spectrum.

The experiments described have been made in the physical laboratory at Leyden, to the Director of which, Professor Kammerlingh Onnes, I am under great obligations for continuous interest in the present subject.

AMSTERDAM, January 1897.

APPENDIX.

Since the publication of my original paper in the *Proceedings* of the Academy at Amsterdam, and while the present paper was in the press, I have become acquainted with two attempts, till now unknown to me, in the same direction, and also with the original account of Faraday's experiment referred to in § 1. The last is to be found in Faraday's *Life* by Dr. Bence Jones, II, 449 (1870) and as it is extremely remarkable I will reprint it here:

1862 was the last year of experimental research. Steinheil's apparatus for producing the spectrum of different substances gave a new method by which the action of magnetic poles upon light could be tried. In January he made himself familiar with the apparatus, and then he tried the action of the great magnet on the spectrum of chloride of sodium, chloride of barium, chloride of strontium, and chloride of lithium.

On March 12 he writes:

Apparatus as on last day (January 28) but only ten pairs of voltaic battery for the electro-magnet.

The colorless gas flame ascended between the poles of the magnet, and the salts of sodium, lithium, etc., were used to give color. A Nicol's polarizer was placed just before the intense magnetic field, and an analyzer at the other extreme of the apparatus. Then the electro-magnet was made, and unmade, but not the slightest trace of effect on or change in the lines in the spectrum was observed in any position of polarizer or analyzer.

Two other pierced poles were adjusted at the magnet, the colored flame established between them, and only that ray taken up by the optic apparatus which came to it along the axis of the poles, *i. e.*, in the magnetic axis, or line of magnetic force. Then the electro-magnet was excited and rendered

neutral, but not the slightest effect on the polarized or unpolarized ray was observed.

This was the last experimental research that Faraday made.

In 1875 we have a paper by Professor Tait, who has kindly sent me a copy, "On a Possible Influence of Magnetism on the Absorption of Light, and some correlated subjects" (*Proc. R. Soc. Edinburgh*, session 1875–6, p. 118). Professor Tait remarks that a paper by Professor Forbes read at the Society, and some remarks upon it by Maxwell, have recalled to him an experiment tried by him several times, but which hitherto has led to no result. Then the paper proceeds:

> The idea is briefly this: The explanation of Faraday's rotation of the plane of polarization of light by a transparent diamagnetic requires, as shown by Thomson, molecular rotation of the luminiferous medium. The plane-polarized ray is broken up, while in the medium, into its circularly polarized components, one of which rotates with the ether so as to have its period accelerated, the other against it in a retarded period. Now, suppose the medium to absorb one definite wave-length only, then — if the absorption is not interfered with by the magnetic action — the portion absorbed in one ray will be of a shorter, in the other of a longer, period than if there had been no magnetic force; and thus, what was originally a single dark absorption line might become a double line, the components being less dark than the single one.

Hence here the idea is perfectly clearly expressed of the experiment, tried in vain; an idea closely akin to that of § 15 above, both being in fact founded on Kelvin's theory of the molecular rotation of the luminiferous medium, though not directly applicable to the experiment of § 9, in which case the lines of magnetic force are perpendicular to the axis of the tube.

In the second place I have to mention two papers by the late M. Fievez, to which attention has been drawn by M. van Aubel, in a letter to Professor Onnes and intended for communication to the Academy of Sciences, Amsterdam. Professor Onnes read the letter at the January meeting, and made at the same time some explanatory remarks of which in the following I make free and extensive use. The papers referred to are: M. Fievez, "De l'Influence du Magnétisme sur les Caractères

des Raies spectrales" (*Bulletin de l'Acad. des Sciences de Belgique*, 3e série, tome **9**, 381, 1885); and Fievez, "Essai sur l'Origine des Raies de Fraunhofer, en rapport avec la Constitution du Soleil" (*l. c.*, 3e série, tome **12**, 30, 1886). Here experiments are described as in §§ 4 and 13 of the present paper. Nothing, however, is observed about the widening of the absorption lines, nor about the polarization of the emitted light. The results obtained by M. Fievez merit careful attention and consideration. He has observed with a flame in a magnetic field not only widening but reversal and double reversal of the lines of the spectrum, the lines at the same time becoming more brilliant. Unfortunately quantitative details are not given. The facts observed in some cases by Fievez are qualitatively not in accordance with my observations or what is to be deduced from my results. Hence even in the cases where the results are qualitatively in accordance, the question remains whether Fievez has observed *the same phenomenon*. The field used by Fievez seems to have been more intense than the one I had at my disposal. Is it possible perhaps to account in this manner for the "double renversement (c'est-à-dire l'apparition d'une raie brilliante au milieu de la raie noire élargie)?" I think the answer must be in the negative. For, arguing from § 19, a line must widen, or else, the field being very intense, become a triplet. We cannot but understand from Fievez's description of the experiment that the light was emitted perpendicular to the lines of force. Now the double reversed line of Fievez is not the triplet to be expected from theory, for it is expressly stated by Fievez that the line experimented upon is not the simple line of the spectrum, but one previously widened and reversed (by some agency independent of magnetism). By the action of magnetism a brilliant line in the center of the black line appears. Hence perhaps one may interpret the case of double reversal as a direct action of magnetism, but then only as a doubling of the absorption line and not as a division of the original lines into three parts. As the application of Lorentz's theory given in § 18 is confessedly only a very first sketch,

further theoretical and experimental evidence is wanted before we are to able to decide whether in the experiment of Fievez a specific action of magnetism on light or perturbing circumstances have been prevalent. Indeed one may make the same objection to M. Fievez's experiment as I myself have made to my own analogous experiment in § 6.

The whole of the phenomena observed by Fievez can readily be attributed to a change of temperature by the well-known actions of the field upon the flame (change in its direction or outline, magnetic convection, etc.); and the last sentence of his paper states that "les phénomènes qui se manifestent sous l'action du magétisme sont identiquement les mêmes que ceux produits par une élévation de température." The negative result obtained by Fievez with absorption spectra would without further consideration (as in § 12) point in the same direction. The inference to be drawn from Fievez's experiments alone would rather be, I think, that the temperature of the flame is changed in his experiments than that a specific action of magnetism on the emission and absorption of light exists. By experiments already in progress I hope to settle the dubious points.

Summarizing we may say: Had the experiments of Fievez come to my knowledge they would have been a motive for me to further investigation, Fievez not having prosecuted his inquiry up to a decisive result. At least at present it remains even doubtful whether the phenomenon observed by Fievez with a magnetized flame is really to be attributed to *the specific action of the magnetic field on the period of the vibrations of light*, which I have found and undoubtedly proved by the experimental confirmation of Lorentz's predictions.

AMSTERDAM, February 1897.

Minor Contributions and Notes.

CURVATURE OF THE SPECTRAL LINES.[1]

In Scheiner's *Spektralanalyse der Gestirne* is given the equation of the curve of the lines as seen in a prism spectroscope. There is no demonstration offered but the reader is referred to a paper by Dit-

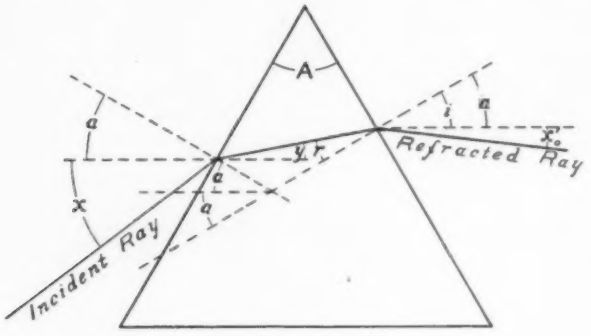


Fig. 1.

scheiner. As this paper is inaccessible to a great many interested in spectroscopic work, and as this equation can be deduced in a very simple manner, I venture to offer my own demonstration as I give it to my students in astrophysics.

Let h = the angle any incident ray makes with the principal section of the prism.

x = the angle its projection on the principal section makes with the bisectrix of the angle between the normals to the two faces of the prism.

x' = the same for the refracted ray.

y = the same for the ray inside the prism.

a = half the angle between the normals to the faces of the prism.

n = the index of refraction.

[1] Since the above was written my attention has been called to a paper on the same subject, by Mr. W. H. M. Christie, published in the *Monthly Notices* for March, 1874. His method of proof is, however, somewhat different from mine and his final results are not in quite the same form as those given in Scheiner.

Then we have from Mascart, *Traite d'Optique*, Tome I., page 85,

$$\sin(a+y) = \frac{\cos h}{\sqrt{n^2 - \sin^2 h}} \sin(a+x) = B \sin(a+x) \qquad (1)$$

$$\sin(a-y) = \frac{\cos h}{\sqrt{n^2 - \sin^2 h}} \sin(a+x') = B \sin(a+x') \qquad (2)$$

add and subtract (1) and (2)

$$2 \sin(a) \cos(y) = B[\sin(a+x) + \sin(a+x')] \qquad (3)$$

$$2 \cos(a) \sin(y) = B[\sin(a+x) - \sin(a+x')] \qquad (4)$$

Square (3) and (4), divide by $\sin^2(a)$ and $\cos^2(a)$ respectively, add and reduce:

$$\sin^2(2a) = B^2 \{[\sin^2(a+x) + \sin^2(a+x')] + 2\cos(2a)\sin(a+x)\sin(a+x')\} \qquad (5)$$

Substitute the value of B in (5),

$$\frac{\sin^2(2a)[n^2 - \sin^2 h]}{\cos^2 h} = \sin^2(a+x) + \sin^2(a+x') + 2\cos(2a)\sin(a+x)\sin(a+x'). \qquad (6)$$

It is evident that with a straight slit for all values of h, x is constant, but x' varies. When $h = 0$ let $x' = x_0'$. When $h = 0$ (6) becomes

$$n^2 \sin^2(2a) = \sin^2(a+x) + \sin^2(a+x_0') + 2\cos(2a)\sin(a+x)\sin(a+x_0'). \qquad (7)$$

Subtract (7) from (6),

$$\left.\begin{aligned} &\sin^2(2a)\left[\frac{n^2 - \sin^2 h}{\cos^2 h} - n^2\right] = \sin^2(a+x') - \sin^2(a+x_0') \\ &+ 2\cos(2a)\sin(a+x)[\sin(a+x') - \sin(a+x_0')] \\ &= [\sin(a+x') - \sin(a+x_0')][\sin(a+x') \\ &+ \sin(a+x_0') + 2\cos(2a)\sin(a+x)] \end{aligned}\right\} (8)$$

$$\left.\begin{aligned} &= 2\cos\left(a + \frac{x' + x_0'}{2}\right)\sin\left(\frac{x' - x_0'}{2}\right) \\ &\left[2\sin\left(a + \frac{x' + x_0'}{2}\right)\cos\frac{x' - x_0'}{2} + 2\cos(2a)\sin(a+x)\right] \end{aligned}\right\} (9)$$

For small values of h, we may put $\cos\frac{x' - x_0'}{2} = 1$, $a + \frac{x' + x_0'}{2} = a + x_0'$, etc.

$$\left.\begin{aligned} &\sin^2(2a)\left[\frac{n^2 - \sin^2 h}{\cos^2 h} - n^2\right] = 4\cos(a + x_0') \\ &\left[\sin(a + x_0') + \cos(2a)\sin(a+x)\right]\sin\frac{x' - x_0'}{2}. \end{aligned}\right\} (10)$$

When h is small the left hand side reduces to $(n^2-1)\sin^2(2a)\sin^2(h)$.

Let r = the angle between the ray inside the prism and normal to the second face of the prism.

i = the angle between the normal to the second face and last direction of the ray.

A = prism angle, then $i=(a+x_0')\ 2a=A\sin(a+x)=n\sin(A-r)$. In the notation of Scheiner $\sin(h)=\frac{Z}{f}=h$ nearly, $x'-x_0'=\frac{X}{f}$, collimator and observing telescope having the same focal length. Making these substitutions (10) becomes, since $\sin\frac{X}{f}=\frac{X}{f}$, nearly,

$$(n^2-1)\sin^2 A\left(\frac{Z^2}{f^2}\right)=-2\cos(i)\left[\sin(i)+n\cos(A)\sin(A-r)\right]\frac{X}{f},$$

since $\sin(i)=n\sin(r)$.

$$Z^2=-\frac{2fn\cos(i)\left[\sin(r)+\cos(A)\sin(A-r)\right]X}{(n^2-1)\sin^2(A)}$$

$$Z^2=-\frac{2nf\cos(i)\cos(A-r)}{(n^2-1)\sin A}\cdot X$$

which is Scheiner's formula.

H. C. LORD.

EMERSON MCMILLIN OBSERVATORY.

ERRATA.

In Dr. Brace's "Note on Steady Liquid Surfaces" in this JOURNAL, **5**, March 1897, p. 215, line 9, for 1″ read 0.″1.

In Professor Campbell's article in this JOURNAL, **5**, April 1897, p. 236, line 12, for Oct. 22, *1895* read Oct. 22, *1896*.

STARS HAVING PECULIAR SPECTRA.[1]

A LIST of stars having peculiar spectra is given in the annexed table. With four exceptions noted below they were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial photographs. The designation of the star, its approximate right ascension and declination for 1900, its catalogue magnitude, and a brief description of its photographic spectrum are given in the successive columns of the table. When the object is not a catalogue star its

[1] Harvard College Observatory, *Circular No. 17*.

position as derived from a photograph, is given in the notes following the table.

Designation	R. A. 1900	Dec. 1900	Mag.	Description
	h m			
.....	0 25.6	−46° 58′	..	Type III. Hydrogen lines bright. Variable.
.....	5 35.1	−69 52	..	Gaseous Nebula. Gal. long. 247° 08′, lat. −31° 43′.
A.G.C. 6633	5 36.0	−34 8	2.5	*Hβ* bright, superposed on broad dark line. α Columbae.
A.G.C. 9313	7 14.5	−24 47	4.6	Peculiar. 30 Can. Maj. Resembles ζ Puppis.
A.G.C. 10182	7 43.9	−25 42	5.3	*Hβ* bright. o Puppis.
−41°3911	8 10.8	−41 24	10	*Hβ*, Hγ, Hδ, and Hζ bright. Resembles η Carinae.
A.G.C. 12465	9 4.8	−70 8	5.2	*Hβ* bright, superposed on broad dark line. E Carinae.
A.G.C. 17542	12 48.8	−56 37	5.5	*Hβ* bright. Companion to μ Crucis.
.....	13 31.1	−55 58	..	Peculiar. Variable.
A.G.C. 19273	14 8.0	−56 37	5.6	*Hβ* bright.
.....	16 21.1	−43 26	..	Type IV.
A.G.C. 22640	16 39.2	−46 54	7.4	Bright band, wave-length about 4700.
−36°11341	17 7.0	−37 0	9.1	Gaseous Nebula. Gal. long. 317° 13′. lat. −0° 45′.
.....	17 11.6	−45 52	..	Type IV.
−7°4689	18 39.1	− 7 12	8.2	*Hβ* bright.
−7°5141	19 55.7	− 7 39	9.8	Type IV.
.....	20 8.5	−44 43	..	Peculiar. Variable.
A.G.C. 29191	21 11.5	−39 15	7.3	Peculiar.
A.G.C. 31272	22 55.0	−23 4	8	Peculiar.

The position of the first star is R. A.=$0^h\ 24^m\ 23^s.9$, Dec.=−47° 6′ 3″ (1875). Dr. De Lisle Stewart, at Arequipa, called attention to the spectrum of this star on a plate taken with the Bruce 24-inch telescope, adding the remark "bright lines (hydrogen?)." On examination by Mrs. Fleming it proved to be variable, having a spectrum of the type characteristic of such stars.

The position of the second object which is in the larger Magellanic Cloud is R. A.=$5^h\ 35^m\ 20^s.0$, Dec.=−69° 52′ 51″ (1875).

The bright band in ζ Puppis having wave-length 4688 is dark in the spectrum of 30 Canis Majoris. This spectrum, like that of the adjacent star, 29 Canis Majoris, was found by the writer to contain the additional hydrogen lines having wave-lengths 3925, 4027, 4202, and 4544.

The bright line in the spectrum of o Puppis was found independently by Dr. Stewart.

The position of the ninth star is R. A.$=13^h\ 29^m\ 32^s.3$, Dec.$-55^\circ\ 50'\ 10''$ (1875). The spectrum of this star may resemble that of ζ Puppis, since it contains two bright lines which may coincide with the lines having wave-lengths 4633 and 4688 in the spectrum of that star. ζ Puppis, 29 Canis Majoris, 30 Canis Majoris, and this star may form a subdivision of Type V. All of these stars are near the central line of the Milky Way.

The bright line in the spectrum of *A. G. C.* 19273 was found by Miss A. J. Cannon.

The position of the eleventh star is R. A.$=16^h\ 19^m\ 15^s.9$, Dec.$-43^\circ\ 22'\ 49''$ (1875).

The thirteenth object,-36° 11341, is *N. G. C.* 6302.

The position of the fourteenth star is R. A.$=17^h\ 9^m\ 46^s.1$, Dec.$-45^\circ\ 49'\ 44''$ (1875).

The position of the seventeenth star is R. A.$=20^h\ 6^m\ 45^s.2$, Dec.$-44^\circ\ 46'\ 59''$ (1875). Dr. Stewart noted "bright line star (faint)" on a Bruce photograph. An examination by Mrs. Fleming shows that the star is variable and that the spectrum is peculiar.

DISTRIBUTION OF STARS IN CLUSTERS.

Professor Bailey has recently made a count of the stars in the vicinity of several clusters. An enlargement was made of a photograph of the Pleiades taken with the Bruce telescope and having an exposure of six hours. A region 2° square, with η Tauri (Alcyone) in the center was divided into 144 smaller squares, each $10'$ on a side. The stars in each of these squares were then counted. The total number thus found was 3972, an average of 28 in each square. The 42 squares including the brighter stars in the group contain 1012 stars, an average of 24 per square. It therefore appears that the total number of stars in the region of the Pleiades is actually less than that in adjacent portions of the sky, of equal area, and it is much less than the corresponding number in many parts of the Milky Way. The Pleiades must, therefore, be regarded, first as a group consisting of comparatively bright stars; secondly, if we omit the bright stars, the number of faint stars will be much less than in the adjacent portions of the sky. This absorption of the faint stars is probably due to the nebulosity surrounding this group. A similar absence of faint stars is noticeable near other diffused nebulae, for example, that surrounding *N. G. C.* 6726–7. This condition would be explained if we assume

that stars have not yet been formed by the condensation of this portion of the nebula or that the latter is less distant and slightly opaque.

A similar count was made of ten regions 6′ square, in the vicinity of η Carinae. The plate used was taken with the 24-inch Bruce telescope, and had an exposure of four hours. From this count it appears that in a region 5° square, and represented in Plate 2, described in *Circular No. 15*, the total number of stars was about 250,000, while the number contained on the entire plate exceeded 400,000.

EDWARD C. PICKERING.

March 30, 1897.

Reviews.

ELECTRO-MAGNETIC WAVES.

Joseph Henry in 1842 writing in regard to the oscillatory character of a Leyden jar discharge says: "A remarkable result was obtained in regard to the distance at which induction effects are produced. A single spark about an inch long produced an induction sufficiently powerful to magnetize needles at a distance of 30 feet," and he is "disposed to adopt the hypothesis of an electrical plenum . . . . and it may be further inferred that the diffusion of motion in this case is almost comparable with that of a spark from a flint and steel in the case of light." (*Scientific Writings of Joseph Henry*, I, 203.) Since then, Maxwell, following the ideas obtained from experiment by Faraday, has developed the theory of magnetic action which requires a medium through which electro-magnetic effects are propagated with the velocity of light. Twenty-five years after this theory was published methods of exciting and observing these waves were worked out by Hertz.

Apparatus.—As is well known Hertz excited waves of comparative shortness by the oscillatory discharge between bodies of low capacity and induction. His vibrator consisted of two zinc plates about 40^{cm} square to which were soldered rods ending in brass balls between which the discharge took place. To excite this system the terminals of the secondary of an induction coil are connected to either plate. Succeeding experimenters have not changed the principle of exciting, the only variation being the reduction of the capacity and self induction of the system by diminishing the dimensions. Such a system generates electro-magnetic waves. These waves are propagated through the ether, being composed of an electrical displacement and a magnetic displacement at right angles to each other, both being perpendicular to the line of propagation. For some experiments they may be conveniently guided along wires. E. Lecher (*Wiener Berichte*, p. 340, 1890) describes a method for this which has been much used. Opposite each of the two plates of a Hertz vibrator an equally large plate is arranged and from each plate is led a long wire, the two wires being parallel. The waves are thus guided along these wires, the produc-

tion of waves in these secondary wires being a phenomenon of resonance.

To detect the waves excited in the ether Hertz used a ring of wire in which a spark gap was inserted. When placed in certain positions relative to the vibrating system surgings were set up in the ring and minute sparks appeared at the spark gap. He called this a resonator, because the sparks were strongest when the natural period of the ring was the same as that of the vibrator. In order to obtain a linear detector the ring resonator has been replaced by two linear resonators, placed along a straight line with the spark gap between the adjacent ends. When these experiments are tried on a small scale the sparks are extremely difficult to observe. To overcome this the spark gap has been replaced by a thermal junction, and the throw of a galvanometer caused by the heating of this junction is taken as a measure of the intensity of the surgings. (Klemencie, *Wied. Ann.*, **42**, 416, Lebedew, *Wied. Ann.*, **56**, 1.) This method has been successfully applied to quantitative work in a particularly skillful manner by Lebedew, who has observed waves of a length $\lambda = 0^{cm}.6$ to $0^{cm}.3$.

Rutherford has developed a method which consists of connecting the ends of the resonators to a minute solenoid wound directly on a core composed of a number of fine steel wires. The method of observation is, (1) magnetize the steel wire core to saturation, (2) observe the deflection of a magnetometer needle due to the steel core, (3) connect the solenoid to the ends of the resonator and if surgings be started in the resonator the oscillatory current through the solenoid will tend to demagnetize the core, (4) again observe the deflection of the magnetometer due to the core. The difference between the deflection when the core was saturated and the last deflection is taken as a measure of the electrical radiation. He has only applied it to comparatively long waves. He finds it extremely sensitive, obtaining effects at a distance of one-half mile after the waves had passed through several brick walls and a number of buildings. (*Phil. Trans.*, **189**, 1–24, 1897.)

An entirely different method of detecting these disturbances depends on the change of electrical resistance of a series of metallic bodies in contact when acted on by electro-magnetic waves, commonly called a coherer. (First pointed out by Branly, *Jour. de Phys.*, **4**, 273.) The coherer has been used by Lodge; and more recently Bose has perfected it. (*Proc. R. Soc.*, **59**, 160.)

Reflection.—Hertz found that when electro-magnetic waves were incident normally on a metal surface he could detect points along the normal for maximum and minimum sparking of the resonator. This demonstrated that the phenomenon was of the nature of a wave motion, the observed points being the loops and nodes of the standing waves caused by the interference of the incident and reflected ray (*Wied. Ann.*, **34**, 609). Further it shows that the velocity of propagation is finite. Hertz considered that twice the distance between points of no sparking was the wave-length, but Sarasin and De la Rue have pointed out that this distance depends entirely on the size of the resonator used.

Wave-length.—For Hertz's shortest waves the wave-length $\lambda = 24^{cm}$. By reducing the capacity and self-induction of the vibrator succeeding experimenters have reduced this as low as $\lambda = 0^{cm}.3$ (Lebedew, *Wied. Ann.*, **56**, 1). Waves between the length $\lambda = 0^{cm}.3$ and Langley's longest heat wave, $\lambda = 0^{cm}.0015$ (Keeler, ASTROPHYSICAL JOURNAL, **3**, 63) yet remain to be observed.

Rectilinear propagation.—If the vibrator be placed in the focal line of a cylindrical parabolic mirror and if the laws of reflection are the same as those for light, then the waves from the vibrator will emerge from the mirror as a parallel beam. And if this beam is incident on a similar mirror placed opposite, whose focal line is parallel to the focal line of the first, a linear resonator placed on this focal line will be excited. Further, if a metal screen of size equal to the opening of the mirror be placed directly between the mirror, no effect is produced by the vibrator on the resonator, thus showing approximate rectilinear propagation (*Wied. Ann.*, **36**, 769).

Polarization.—If the waves composing the above beam follow the laws of light waves, the beam emerging from the parabolic mirror is plane polarized. This may be experimentally proved by rotating the receiving mirror and resonator about the ray as an axis. The action in the resonator becomes more and more feeble, and when the focal lines of the two mirrors are at right angles no effect is obtained, the two mirrors acting like polarizer and analyzer. And if the radiation pass a grating of parallel conducting wires only the electrical vibrations perpendicular to the wires will be transmitted, and the ray is plane polarized. By using two such gratings and crossing the wires at different angles, circular and elliptical polarization may be produced.

The question as to whether the electrical or magnetic displacement

is perpendicular to the plane of polarization has been investigated by Trouton (*Nature*, **39**, 172). When a polarized beam is incident on a non-conducting surface at the polarizing angle, $\tan^{-1}\mu$, he found that if the electrical displacement is in the plane of incidence none of the radiation is reflected, if the magnetic displacement is in the plane of incidence a portion of the radiation is reflected. Therefore, in a plane polarized beam the electrical vibration is perpendicular to the plane of polarization. The disturbance considered by Fresnel is the electrical displacement, while that of Mac Cullagh is the magnetic displacement; and Maxwell's theory that the magnetic force is in the plane of polarization is verified.

Refraction of the beam takes place when passing from one insulating medium to another. Hertz showed this by observing the change in direction of the beam caused by a large pitch prism and thus calculated the index of refraction. A large number of measurements of indices of refraction have since been made by this and other methods. Bose points out that an excellent way to determine the index is to observe the angle of total reflection (*Proc. R. Soc.*, **59**, 160).

Double refraction was demonstrated by Righi (*Mem. R. Accad. delle Scienze, Bologna* (4), **4**, 487; *Wied. Ann.*, **55**, 389) and simultaneously by Mack (*Wied. Ann.*, **54**, 342). If the mirrors be set with their focal lines at right angles, in general the resonator is not excited. But if a block of wood be placed between them so that the grain is perpendicular to the line of propagation of the ray and at 45° to the focal lines of the mirrors, the resonator will be excited, due to what may be called double refraction by the wood. Lebedew has investigated double refraction in crystals and carried the analogy to optics so far as to construct Nicol prisms and $\frac{1}{4}\lambda$ plates (*Wied. Ann.*, **56**, 1). Bose noted that the absorption was greater when the electrical vibrations are parallel to the fibrous direction in the crystal and least when perpendicular to the fiber. Bose had measurements made of the conductivity in the two directions and concludes that the absorption in various directions is proportional to the conductivity in these directions (*Proc. R. Soc.*, **60**, 433).

Interference of electro-magnetic waves in air was observed by Hertz in his original experiments on reflection. A recent application of interference is that of Bose (*Proc. R. Soc.*, **60**, 167) for obtaining a *pure spectrum of electric radiation* by means of diffraction gratings, the gratings being formed by strips of foil. The spectrum found appears well

defined, linear and not continuous. By this method the wave-length may be accurately determined. Interference has been of particular value in studying the propagation of the waves along a resonating system of parallel wires, as described by Lecher (*Wiener Berichte*, p. 340, 1890). If a rarefied tube be placed between the ends of the wires, it will glow, on account of the electrical oscillation in the wires. If the parallel wires be connected by a cross wire, the luminosity in general ceases. If the wire bridge be moved back and forth along the wires some sharply defined positions of the bridge are found which cause the tube to become luminous; and from a knowledge of these positions and the lengths of the wires the wave-length is determined.

Barton, with an electrometer to detect the nodes and loops, has investigated the effect of replacing a portion of the parallel wires by conductors with a capacity per unit length different from the original wires. He considers, (1) the partial reflection at the beginning of the abnormal part, (2) the partial reflection at the end of the abnormal part, (3) the interference between the two sets of waves thus reflected. He finds that as the length of the abnormal part is increased the total energy of the reflected wave is periodically increased and decreased. Thus the experiment is parallel to the optical phenomenon of *Newton's Rings*, the abnormal part of the wire corresponding to the air film. (Final paper, *Proc. R. Soc.*, **57**, 68.) In such experiments as the last the reflection of waves from the ends of the wires is troublesome. Barton describes a method for overcoming this (*Phil. Mag.*, **43**, 39).

Dispersion.—Garbasso and Aschkinass (*Wied. Ann.*, **53**, 534) constructed a prism inclosed in which were a number of tinfoil strips to act as resonators, the strips being all of the same dimensions. On passing the usual parallel beam of wave through this prism, and examining the transmitted wave by resonators of different periods they appear to find dispersion into a sort of spectrum. If this experiment be correct it supports Helmholtz's theory of dispersion. Garbasso and Aschkinass think it shows that the simple two-sphere generator gives waves of various periods which are refracted at different angles. This is contrary to theory and to the experiment of Bose with diffraction gratings. (*Proc. R. Soc.*, **60**, 167.)

Drude, while working on dispersion, found that waves 10^{cm} long are much more strongly damped in alcohol and especially in glycerine than in water or aqueous salt solutions. Theoretically the damping should increase with the conductivity, but the badly conducting liquids

are found to damp electrical waves as much as a 5 per cent. solution of copper sulphate, which is some thousand times better conductor. That is, alcohol and glycerine give absorption bands for waves of 10^{cm} length, which would indicate, according to the common theory of absorption, that the molecules of these compounds have a free period corresponding to a period of a 10^{cm} wave. In this same investigation Drude further notes that glycerine and alcohol show anomalous dispersion for waves of about the above length. (*Wied. Ann.*, **58**, 1.)

Relations of K and μ.—A result of Maxwell's electro-magnetic theory of light is that the square of the index of refraction is equal to the specific inductive capacity of the substance. For some permanent gases, liquid hydrocarbon, sulphur, and paraffin, the relation approximately holds, but in general K, the specific inductive capacity, as measured in a slowly varying field, is greater than μ^2. J. J. Thompson (*Proc. R. Soc.*, **46**, 292) and Blondlot (*C. R.*, **112**, 1058, 1891) find that if the specific inductive capacity be determined for electrical waves of high frequency the value of K decreases as the period of the waves becomes shorter. They therefore consider it probable that if K could be measured for waves of the same length as those used to determine the index of refraction the above relations would more nearly hold. On the other hand, E. Lecher (*Phil. Mag.*, **31**, 172) finds that the value of K increases as the period decreases.

Velocity.—Another conclusion from Maxwell's theory is that the velocity of electro-magnetic waves guided by a wire is equal to their velocity in air, this velocity being identical with the velocity of light.

By observing the lengths of the standing waves in a secondary circuit tuned to resonance with the vibrator, and calculating the period of the vibrator from Lord Kelvin's formula for the period of a condenser discharge, $T = 2\pi\sqrt{LC}$, E. Lecher obtained a value for the velocity along wires within about 2 per cent. of the velocity of light (*Wiener Berichte*, p. 340, 1890). Sarasin and De la Rue have demonstrated that the velocity along wires is the same as that in air (*Arch. de Genève*, **29**, 358, 441, 1893, extract of same, *Nat.*, **48**, 252). The same investigators, by observing the nodes in the stationary waves obtained by reflection from a large metallic mirror, and using the calculated period of the vibrator, find the velocity in air to be approximately the velocity of light (*Phys. Gesell. Berlin*, Jan. 6, 1893, extract in *Nat.*, **47**, 336). Blondlot, still using the calculated period and thus making the result not yet independent of theory, found $v = 2.976$

$\times 10^{10}$ cm per second (*C. R.*, **113**, 628, 1891). From the same experiment $v = 3.028 \times 10^{10}$ cm per second with the period as recalculated by Mascart (*C. R.*, **118**, 277, 1894). By actually observing the time required for a discharge to travel a wire 1029^{m} long Blondlot found $v = 2.964 \times 10^{10}$ cm per second. Another experiment over 1821^{m} wire gave 2.980×10^{10} cm per second. His method for observing the time of propagation was to photograph by a rotating mirror a spark through a short circuit and also the spark which had traversed the measured wire. As both sparks were caused by the same condenser discharge the interval of time between the two measures the time required by the second spark to traverse the wire (*C. R.*, **117**, 543, 1893).

Trowbridge and Duane also used a method for determining v depending on the principle of resonance. A primary oscillator and secondary circuit were tuned to resonance, and the nodes and loops of the stationary waves set up in the secondary were measured by means of a bolometer. The period was obtained by photographing the secondary spark after reflection from a rotating mirror. Thus, knowing wavelength and period, v is directly calculated. They found for v, 2.816×10^{10} cm per second (*Am. Jour. Sci.*, **49**, 297, April 1895), and later after some improvements, $v = 3.0024 \times 10^{10}$ cm (*Am. Jour. Sci.*, **50**, 104, August 1895). By a similar method Saunders obtains as the most probable result $v = 2.997 \times 10^{10}$ (*Phys. Rev.*, **4**, 81). Thus the velocity of electric propagation is identical with the velocity of light.

(Reference should be made to a book which contains the best systematic account of the subject: "L'Ottica delle Oscillazioni Elettriche," Augusto Righi, Bologna.)

GEO. W. MIXTER.

JOHNS HOPKINS UNIVERSITY.
April 1897.

Elementary Text-book on Physics. By ANTHONY and BRACKETT. Revised by W. F. MAGIE. Wiley & Sons, New York, 1897, pp. 512.

WE HAVE before us a thoroughly modern work — modern in the best sense of the word — embodying the views of the best men of all times, including our ablest contemporaries, a work which is the product of no small amount of experience.

To one who has waded through the disconnected pages of Ganot or Deschanel, impressed mainly by the multiplicity of apparatus

employed in the study of physics, to one who has thus familiarized himself with many methods and has yet to learn good method, the present volume will prove very refreshing.

The subjects treated do not differ essentially from those discussed in the majority of texts. The same may be said of the order of the treatment. As exceptions to the two statements just made may be mentioned nine pages devoted to gravitational potential, a two-page summary of results from Helmholtz's *Memoirs on Vortex Motion*, ten pages given to the simpler mathematics of the kinetic theory of gases, and a couple of pages on Ewing's *Molecular Theory of Magnetism*.

If then it be asked what is the distinguishing feature of the book, the reply is unity of method in treatment. Fields of force and equipotential surfaces are introduced in the discussion of general dynamics; waves are first presented, under the mechanics of fluids, by a summary, perhaps too short, of the work of the Weber brothers. A general treatment of waves is prefixed also to the discussion of sound. The result is that the potential theory and the theory of waves may thereafter be freely used throughout the book. And in general the treatment of sound, heat, light, electricity, and magnetism may be described as dynamical.

This method is by no means exclusively true of the book before us. The altogether excellent *Theory of Physics* by Ames presents in a most admirable manner the unity of the subjects studied under the head of physics.

There are, however, some omissions which we cannot help wishing Professor Magie had seen fit to make. Among these may be cited the *unproved* expression for the amount of twist (angular displacement) produced in a given wire by a given couple (Eq. 47), or Ampère's expression for the action of one current element upon another (Eq. 103). If one of the chief aims of laboratory work be to discourage the all too easily acquired habit of taking things for granted, may it not be wise, in the lecture room, to reduce to a minimum the formulæ which we ask the student to take without proof.

As illustrating what your reviewer considers always desirable may be cited the articles on the "Propagation of Sound," where the student is *not* left with the bare assertion that

$$V=\sqrt{\frac{E}{D}}$$

but is furnished with the rigid proof of Rankine. The same might

have been done in as simple a way (Tait's demonstration) for the speed of transversal disturbances in strings,

$$V=\sqrt{\frac{T}{\mu}}$$

But one does not need to teach physics very long to find that however excellent a text-book may be, considered alone and by itself, it is a matter of no small difficulty for any instructor other than the author to use the book in his class room. It is, therefore, very much to be hoped that, in the near future, universities will be able to employ men who are competent to write their own books, and who prefer to write their own books, and that the universities will make it possible for these men to print their own books. H. C.

Analyse spectrale directe des Minéraux. Par ARNAUD DE GRAMONT. Paris, Boudry et Cie., pp. 207.

THE author of this work having found that certain minerals are sufficiently good conductors to permit an electric spark to be passed between fragments used as electrodes, undertook to establish a system of direct qualitative analysis based upon observations with a small laboratory spectroscope. The method of analysis is simple, and apparently well adapted to the ordinary requirements of the chemical laboratory. A strongly condensed induction spark, taken between fragments of the mineral held in platinum clips, is examined with a direct vision spectroscope containing two compound prisms, giving an angular separation of the D lines amounting to something over 1′. In the violet the absorption of these prisms is so marked that but one of them can be employed. The observing telescope contains a scale of 250 parts, and the measures are made by simply estimating the positions of the lines with reference to the scale divisions. The wave-lengths of the standard lines used in forming the reduction curve are those of Thalén, and all the measures are therefore based upon his results. The author considers his wave-lengths to be reliable to a single Ångström unit. They are consequently better adapted to the purposes of the analytical chemist than to those of the astrophysicist.

M. de Gramont finds that the spectrum of sulphur can be obtained without the aid of a vacuum tube, by simply passing the condensed spark between two points of platinum or carbon which have been

dipped in melted sulphur and allowed to cool. The chlorides give the spectrum of chlorine in addition to that of the metal, and iodine can also be recognized in its compounds. Tables of the wave-lengths of the principal lines in the spectra of nearly one hundred minerals, with accompanying descriptive matter and several plates, complete the volume. G. E. H.

Some Experiments on Helium. By MORRIS W. TRAVERS. *Proc. R. Soc.*, **60**, 449–453, 1897.

THE investigation which forms the subject of this paper directly concerns the evidence in favor of the *mixture* theory of clèveite gas. Upon diffusing the gas through an asbestos plug, Runge and Paschen noticed a change in the relative intensity of the two sets of lines into which they had divided its spectrum. This strengthened the conclusion already drawn, that the gas is a mixture. They stated, however, that this change might have been due to the reduction of pressure, as the latter was lower in the tube containing the diffused gas than in the other. It was subsequently noticed that the gas was absorbed by the platinum deposited on the walls of the tube, and the possibility of separating the supposed constituents by a process of selective absorption suggested itself to Mr. Travers. In his experiments, a tube was filled with clèveite gas under 3^{mm} pressure, and the current turned on, resulting in the following succession of colors in the tube: (1) yellow, slightly red, (2) bright yellow, (3) yellowish green, (4) green, (5) green, with phosphorescence, (6) phosphorescent vacuum; spark between electrodes outside of tube. After testing for vacuum by means of a pump the tube was heated, resulting in the discharge of gas from the platinum, and the succession of the above colors in reversed order. This showed that all the gas had been absorbed by the platinum and was given out again under the influences of heat.

The tube was now refilled, run to state (4), and exhausted. Upon reheating we should expect a yellow or a green glow, according as the color change was due to selective absorption of a yellow constituent, or to a reduction of pressure in the tube. The resulting illumination, which was green, therefore seemed to prove it to be due to this latter cause.

The relative absorptions of different gases by the platinum is touched upon in the paper. In particular argon is found to be taken

up very slowly, and may be freed from some of its impurities in this manner.

From all that is contained in the paper there seems to have been no systematic observation of the relative intensities of the spectral lines during the changes described, casual reference to the green line only appearing. In view of the systematic variation in each of the two sets reported by Runge and Paschen, and referred to above, it is to be regretted that the experiments were not extended so as to confirm it. However, the paper is a valuable contribution, and coming as it does when the status of the *mixture* theory is somewhat doubtful, its appearance is most opportune.

W. H. WRIGHT.

YERKES OBSERVATORY,
April 1897.

Recent Publications.

A LIST of the titles of recent publications on astrophysical and allied subjects will be printed in each number of the ASTROPHYSICAL JOURNAL. In order that these bibliographies may be as complete as possible, authors are requested to send copies of their papers to both Editors. For convenience of reference, the titles are classified in thirteen sections.

1. THE SUN.

BACKLUND, O. Beobachtungen der totalen Sonnenfinsterniss auf Nowaja Zemlja am 8 August, 1896. A. N. **143**, 17–19, 1897.

DESLANDRES, H. L'éclipse totale de Soleil au Japon. Bull. Soc. Astr. France, 96–98, March 1897.

DESLANDRES, H. Photographie d'une protubérance extraordinaire. C. R. **124**, 171–173, 1897.

GLASENAPP, S. von. Ueber die Expedition der Russischen Astron. Gesellschaft zur Beobachtung der totalen Sonnenfinsterniss am 8 August, 1896. A. N. **143**, 21–23, 1897.

GUILLAUME, J. Observations du Soleil à l'observatoire de Lyon pendant le quatrième trimestre de 1896. C. R. **124**, 449–451, 1897.

HALE, GEORGE E. Review of: Total Eclipse of the Sun, April 16, 1893; J. Norman Lockyer. Ap. J. **5**, 220–226, 1897.

HANSKY, A. L'éclipse totale de Soleil du 9 Août, 1896. Bull. Soc. Astr. France, 89–95, March 1897

HARZER, PAUL. Remarks on the Articles of Mr. E. J. Wilczynski in this JOURNAL, Vol. IV, No. 2. Ap. J. **5**, 36–37, 1897.

JEWELL, LEWIS E. Oxygen in the Sun. Ap. J. **5**, 99–100, 1897.

KOSTINSKY, S. Ueber die Photographien der Corona während der totalen Sonnenfinsterniss, 1896, August 8. A. N. **143**, 19–21, 1897.

SCHUSTER, ARTHUR. Oxygen in the Sun. Ap. J. **5**, 162–163, 1897.

SYKORA, J. Ueber die Grösse der Sonnendurchmessen in verschiedenen Richtungen während der Finsterniss vom 8 August, 1896. A. N. **143**, 23–25, 1897.

TACCHINI, P. Résumé des observations solaires faites à l'observatoire royal du Collège romaine pendant le second semestre 1896. C. R. **124**, 274–276, 1897.

TACCHINI, P. Résumé of Solar Observations made at the Royal Observatory of the Roman College during the Second Half of 1896. Ap. J. **5**, 159–161, 1897.

WOLFER, A. Prov. Sonnenflecken-Relativzahlen. Meteorolog. Zeitschr. **14**, 80, February 1897.

WOLFER, A. Provisorische Sonnenflecken-Relativzahlen für das III Quartal von 1896. Meteorolog. Zeitschr. **13**, 444, 1896.

3. STARS AND STELLAR PHOTOMETRY.

COMSTOCK, GEORGE C. On the Application of Interference Methods to the Determination of the Effective Wave-length of Starlight. Ap. J. **5**, 26–35, 1897.

HAGEN. Atlas veränderlicher Sterne. V. J. S. Astron. Gesellsch. **31**, 250, 1896.

PARKHURST, J. A. The Missing Star BD.+7° 5106. A. N. **142**, 353, 1897.

VILLIGER, W. Bemerkung bez. BD.+23° 699 und −2° 5842. A. N. **142**, 337, 1897.

WILLIAMS, A. S. On the Period of the Variable Star, V Puppis. A. N. **143**, 26–27, 1897.

WOLF, M. Die gegenwärtige Helligkeit der Nova (T) Aurigae. A. N. **142**, 373, 1897.

4. STELLAR SPECTRA, DISPLACEMENTS OF LINES AND MOTIONS IN THE LINE OF SIGHT.

BÉLOPOLSKY, A. On the Spectroscopic Binary α^1 Geminorum. Ap. J. **5**, 1–7, 1897.

FOWLER, A. The Chemistry of the Stars. Knowl. **20**, 77–78, 1897.

FOWLER, A. Chemistry of the Stars. Knowl. **20**, 98, 1897.

KAYSER, H. On the Spectrum of ζ Puppis. Ap. J. **5**, 95–96, 1897.

LOCKYER, J. N. On the Iron Lines Present in the Hottest Stars. Preliminary Note. Proc. R. Soc. **60**, 475–476, 1897.

MAUNDER, E. WALTER. Chemistry of the Stars. Knowl. **20**, 98–99, 1897.

PICKERING, EDWARD C. The Spectrum of ζ Puppis. Ap. J. **5**, 92–94, 1897.

5. PLANETS, SATELLITIES AND THEIR SPECTRA.

COHN, F. Bestimmung der Bahnelemente des V. Jupitersmondes. A. N. **142**, 289–337, 1897.

DOUGLAS, A. E. Projections on the terminator of Mars, and Martian Meteorology. A. N. **142**, 364–366, 1897.

EDITOR BULL. SOC. ASTR. FRANCE. Observations de la planète Mars faites à l'observatoire de Juvisy. Bull. Soc. Astr. France, **11**, 37–42, 1897.

FAUTH, P. Flecke auf Jupiter. A. N. **142**, 375, 1897.

FLAMMARION, C. Suite des observations de Mars faites à l'observatoire de Juvisy. Bull. Soc. Astr. France, 113–118, March 1897.

KEELER, JAMES E. Review of: Observatory Atlas of the Moon. (Lick Observatory.) Ap. J. **5**, 150–151, 1897.

KEELER, JAMES E. Photographic Studies of the Moon at the Paris Observatory. Ap. J. **5**, 51–59, 1897.

KLEIN, DR. Eine Neubildung auf dem Monde. Sirius, **26**, 52–57, 1897.

KRIEGER, J. N. Der Lichtschein im Plato. Sirius, **26**, 49–52, 1897.

LOWELL, P. Libration of Venus and Mercury. A. N. **142**, 363, 1897.

LOWELL, P. The Rotation Period of Venus. A. N. **142**, 361–363, 1897.

NYLAND, A. A. Jupiter-Beobachtungen in Utrecht. A. N. **142**, 265–267, 1897.

PERROTIN, J. Sur la planète Mars. C. R. **124**, 340–346, 1897.

PRINZ, F. Esquisses sélénologiques, II. Ciel et Terre, **18**, 57–70, 1897.

RHEDEN, JOSEPH. Mars-Beobachtungen, 1896. Sirius, **26**, 58–61, 1897.

SCHIAPARELLI, G.-V. Observations de la planète Mars. Bull. Soc. Astr. France, 107–113, March 1897.

SCHUR, W. Bestimmung des Durchmessers und der Abplattung des Planeten Mars. A. N. **142**, 347–349, 1897.

WELLMAN, V. Bemerkungen über die Entstehung der Mondkrater. A. N. **142**, 355, 1897.

6. COMETS, METEORS AND THEIR SPECTRA.

EGINITIS, D. Observation des étoiles filantes du 12 décembre 1896, à Athènes. C. R. **124**, 68, 1897.

FOOTE, W. M. Note on a new Meteorite from the Sacramento Mounains, N. M. Am. Jour. Sci. (4) 3, 65–66, 1897.

HOLETSCHEK. Helligkeiten und Schweife verschiedener Cometen. V. J. S. Astr. Geselsch, **31**, 250, 1896.

NYLAND, A. A. Die Perseien von 1896. A. N. **142**, 263–265, 1897.

RIGGENBACH, A. Beobachtungen der Leoniden 1896. A. N. **142**, 354, 1897.

7. NEBULÆ AND THEIR SPECTRA.

BIGOURDAN, G. Nebuleuses nouvelles, découvertes à l'observatoire de Paris. C. R. **123**, 1243–1245, 1896; **124**, 65–67; 133–135, 1897.

ROBERTS, ISAAC. Photograph of the Great Nebula in Orion. Knowledge, **20**, 100–101, 1897.

8. TERRESTRIAL PHYSICS.

BAUER, L. A. Vertical Earth-air Electric Currents. Terres. Mag. **2**, 11–23, 1897.

CHREE, CHARLES. Magnetic Work at the Kew Observatory. Terres. Mag. **2**, 23–26, 1867.

PUTNAM, G. R. Results of Magnetic Observations on the Greenland Expedition of May 1896. Terres. Mag. **2**, 32–34, 1897.

9. EXPERIMENTAL AND THEORETICAL PHYSICS.

BALMER, J. J. A New Formula for the Wave-lengths of Spectral Lines. Ap. J. **5**, 199–209, 1897.

BECQUEREL, H. Recherches sur les rayons uraniques. C. R. **124**, 438–444, 1897.

BERTHELOT, M. Recherches sur l'hélium. C. R. **124**, 113–119, 1897.

FITZGERALD, GEORGE F. Note on a Cause for the Shift of Spectral Lines. Ap. J. **5**, 210–211, 1897.

HUMPHREYS, W. J. A Further Study of the Effect of Pressure on the Wave-lengths of Lines in the Arc-spectra of certain Elements. Ap. J. **4**, 249–262, 1896.

MCKISSICK, A. F. Becquerel Rays. Sci. Am. Sup. **43**, 17542, 1897.

LARMOR, J. The Influence of a Magnetic Field on Radiation Frequency. Proc. R. Soc. **60**, 514–515, 1897.

LÉPINAY, J. MACÉ DE. Sur les changements de phase par diffraction. Séances Soc. Franc. Phys. 203–205, 1896.

LODGE, O. The Influence of a Magnetic Field on Radiation Frequency. Proc. R. Soc. **60**, 513–514, 1897.

RAMSAY, W. and TRAVERS, M. W. The Gaseous Constituents of certain Mineral Substances and Natural Waters. Proc. R. Soc. **60**, 442–448, 1897.

REINERDES, ERNST. Untersuchungen über die Ausdehnung des Quarzes durch die Wärme. Jena 1896.

TILDEN, W. A. On the Gases Enclosed in Crystalline Rocks and Minerals. Proc. R. Soc., **60**, 453–457, 1897.

TRAVERS, M. W. Some Experiments on Helium. Proc. R. Soc. **60**, 449–453, 1897.

TROWBRIDGE, J. Does a Vacuum conduct Electricity? Am. Jour. Sci. (4) 3, 343, 1897.

TROWBRIDGE, J. and RICHARDS, T. W. Temperature and Ohmic Resistance of Gases During the Oscillatory Electric Discharge. Am. Jour. Sci. (4), 3, 327–342, 1897.

WILSON, W. E. and FITZGERALD, G. F. On the Effect of Pressure in the surrounding Gas on the Temperature of the Crater of an Electric Arc. Proc. R. Soc. **60**, 377–383; 1897. Ap. J. **5**, 101–108, 1897.

10. THE SPECTRA OF THE ELEMENTS.

AMES, J. S. and HUMPHREYS, W. J. On the Spectrum of Heavy and Light Helium. Ap. J. **5**, 97–98, 1897.

HASSELBERG, H. On the Occurrence of Vanadium in Scandinavian Rutile. Ap. J. **5**, 194–198, 1897.

TROWBRIDGE, J. and RICHARDS, T. W. The Multiple Spectra of Gases. Am. Jour. Sci. (4) **3**, 117–120, 1897.

TROWBRIDGE, J. and RICHARDS, T. W. The Spectra of Argon. Am. Jour. Sci. (4) **3**, 15–20, 1897.

12. INSTRUMENTS AND APPARATUS.

BARUS, C. On a Possible Development of the Idiostatic Electrometer. Phys. Rev. **4**, 400–404, 1897.

BRACE, D. B. Note on Steady Liquid Surfaces. Ap. J. **5**, 214–215, 1897.

BROGA, A. Galvanomètre absolument astatique et à grande sensibilité. Séances Soc. Franç. Phys. 249–253, 1896.

CHARLIER. Construction astronomischer und photographischer Objective. V. J. S. Astron. Gesellsch. **31**, 250, 1896.

HALE, GEORGE E. On the Comparative Value of Refracting and Reflecting Telescopes for Astrophysical Investigations. Ap. J. **5**, 119–131, 1897.

HALE, GEORGE E. Note on a Form of Spectroheliograph suggested by Mr. H. F. Newall. Ap. J. **5**, 211–213, 1897.

HUGGINS, WILLIAM. On an Automatic Arrangement for Giving Breadth to Stellar Spectra on a Photographic Plate. Ap. J. **5**, 8–10, 1897.

PICKERING, E. C. The Bruce Photographic Telescope. A. N. **142**, 367–369, 1897.

RITCHEY, G. W. On a Support System for Large Specula. Ap. J. **5**, 143–147, 1897.

STREHL, K. Ueber die Farbenabweichung der Fernrohrobjektive und des Auges. Z. f. Instrum. **7**, 77–81, March 1897.

VOGEL, H. C. The Absorption of Light as a Determining Factor in the Selection of the Size of the Objective for the Great Refractor of the Potsdam Observatory. Ap. J. **5**, 75–91, 1897.

WADSWORTH, F. L. O. On a New Form of Mounting for Reflecting Telescopes devised by the Late Arthur Cowper Ranyard. Ap. J. **5**, 132–142, 1897.

13. General Articles.

Editor of Astrophysical Journal. On the Mode of Printing Maps of Spectra. Ap. J. **5**, 216, 1897.

Editor of Scientific American. Mountain Observatories. (Condensed from "Mount. Obs. in Amer. and Europe," by Dr. E. S. Holden, in Smithsonian Miscel. Collections.) Sci. Am. Sup. **43**, 17546–17548, 1897.

General Committee. Report of the Condition and Progress of the G. V. Juggarow Observatory, Vizagapatam, Including results of Observations for the Year 1895. Calcutta, 1896.

Hale, George E. The Yerkes Observatory of the University of Chicago. I. Selection of the Site. Ap. J. **5**, 164–180, 1897.

Ligondès, du. Sur la formation du système solaire. C. R. **124**, 396–398, 1897.

Schmidt, Adolf. On the Distribution of Magnetic Observatories over the Globe. Terres. Mag. **2**, 27–31, 1897.

Wiedemann, E. Luminescenz und astrophysikalische Probleme. V. J. S. Astron. Gesellsch. **31**, 250, 1896.

INDEX TO VOLUME V.

SUBJECTS.

PAGE

ABSORPTION in the Objective of the Great Potsdam Refractor. *H. C. Vogel* - - - - - - - - - - - - - 75
AQUEOUS Vapor in the Atmosphere, Variation of. *L. E. Jewell* - 279
ARC, Electric, Effect of Pressure on the Temperature of. *W. E. Wilson and G. F. Fitzgerald* - - - - - - - - - 101
ARC-SPECTRA of Cobalt and Nickel, III. *B. Hasselberg* - - - 38
ARENDT'S Spectroscopic Investigation of the Variation of Aqueous Vapor in the Atmosphere *L. E. Jewell* - - - - - 279
ATMOSPHERE, Variation of Aqueous Vapor in the. *L. E. Jewell* - 279
AURIGAE, NOVA, Spectrum of. *W. W. Campbell* - - - - - 238
Professor Campbell's Observations of. *E. E. Barnard* - - 277
BARNARD, Award of the Gold Medal of the R. A. S. to Professor. *George E. Hale* - - - - - - - - - - - 215
BINARY, Spectroscopic, α^1 Geminorum. *A. Bélopolsky* - - - 1
BOLOMETER, Thermal Measurements with the, by the Zero Method. *F. L. O. Wadsworth* - - - - - - - - - - 268
CAMPBELL'S Observations of Nova Aurigæ. *E. E. Barnard* - - 277
Z CENTAURI. *W. W. Campbell* - - - - - - - - - 233
CLUSTERS, Distribution of Stars in. *E. C. Pickering* - - - 352
COBALT and Nickel, Arc-Spectra of. III. *B. Hasselberg* - - 38
COMET 1896, III (Swift), Spectrum of. *W. W. Campbell* - - - 238
1895, IV (Perrine), Spectrum of. *W. W. Campbell* - - - 237
1896, I (Perrine), Spectrum of. *W. W. Campbell* - - - 237
1895, V (Brooks), Spectrum of. *W. W. Campbell* - - - 237
1889–96 (Brooks-Javelle), Spectrum of. *W. W. Campbell* - 238
CORONA, Photography of. *D. P. Todd* - - - - - - - 318
CURVATURE of Lines in Spectroheliograph, Correcting. *W. H. Wright* - - - - - - - - - - - - - 325
of Spectral Lines. *H. C. Lord* - - - - - - - - - 348
DARKNESS of Sun-spots, Cause of. *J. Evershed* - - - - 244
EFFECTIVE Wave-length of Starlight. *George C. Comstock* - - 26
ELECTRIC Arc, Effect of Pressure on the Temperature of. *W. E. Wilson and G. F. Fitzgerald* - - - - - - - - - 101
FLUID Prism, New Form of. *F. L. O. Wadsworth* - - - - 149
FOCUS, Determining, of an Objective. *H. C. Lord* - - - - 305

PAGE

FORMULA for the Wave-lengths of Spectral Lines. *J. J. Balmer* - 199
α^2 GEMINORUM, Spectroscopic Binary. *A. Bélopolsky* - - - - 1
GOULD, Benjamin Apthorp. - - - - - - - - - - - 50
HELIUM, Spectra of Heavy and Light. *J. S. Ames and W. J. Humphreys* - - - - - - - - - - - - - 97
HYDROGEN, Spectrum of. *H. Kayser* - - - - - - - - 243
INTERFERENCE Methods applied to determine Effective Wave-length of Starlight. *George C. Comstock* - - - - - - - - 26
LIGHT, Influence of Magnetism on, Emitted by a Substance. *P. Zeeman* - - - - - - - - - - - - - - 332
LINES, Curvature of Spectral. *H. C. Lord* - - - - - - 348
in Spectroheliograph, Correcting Curvature of. *W. H. Wright* 325
LIQUID Surfaces, Steady. *D. B. Brace* - - - - - - - - 214
MAGNETISM, Influence of, on the Nature of the Light Emitted by a Substance. *P. Zeeman* - - - - - - - - - - - 332
MAPS of Spectra, Mode of Printing. - - - - - - - - - 216
MARS, Spectrographic Observations of in 1896–7. *James E. Keeler* 328
Spectrum of. *W. W. Cambpell* - - - - - - - - 235
METALS, Arc-Spectra of the. III. Cobalt and Nickel. III. *B. Hasselberg* - - - - - - - - - - - - - - - 38
MICROMETRICAL Measurements of Venus. *E. E. Barnard* - - 299
MOON, Photographic Studies of, at the Paris Observatory. *K.* - - 51
MOUNTING, Coudé, for Reflecting Telescopes. *F. L. O. Wadsworth* 132
G. E. H. - - - - - - - - - - - - - - - 143
NEWALL'S form of Spectroheliograph. *George E. Hale* - - - 211
NICKEL and Cobalt, Arc-spectra of. III. *B. Hasselberg* - - 38
OBJECTIVE for the Great Potsdam Refractor. *H. C. Vogel* - - 75
Determining Focus of. *H. C. Lord* - - - - - - - 305
OXYGEN in the Sun. *L. E. Jewell* - - - - - - - - - 99
Arthur Schuster - - - - - - - - - - - - 162
PARIS Observatory, Photographic Studies of the Moon at the. *K.* - 51
PHOTOGRAPHIC Studies of the Moon at the Paris Observatory. *K.* - 51
PHOTOGRAPHY of the Corona. *D. P. Todd* - - - - - - - 318
POTSDAM Observatory, Objective for the Great Refractor. *H. C. Vogel* 75
PRESSURE, Effect of, on the Temperature of an Electric Arc. *W. E. Wilson and G. F. Fitzgerald* - - - - - - - - 101
PRINTING Maps of Spectra, Mode of. - - - - - - - - 216
PRISM, New Form of Fluid. *F. L. O. Wadsworth* - - - - - 149
ζ PUPPIS, Spectrum of. *E. C. Pickering* - - - - - - - - 92
H. Kayser - - - - - - - - - - - - - 95
RANYARD Mounting for Reflecting Telescopes. *F. L. O. Wadsworth* 132
G. E. H. - - - - - - - - - - - - - - - 148

PAGE

Recent Publications, pp. 71, 154, 227, 293, 365.
Reviews, pp. 60, 150, 219, 282, 354.
REFLECTING Telescopes, Coudé Mounting for. *F. L. O. Wadsworth* 132
G. E. H. - - - - - - - - - - - - - 143
and Refracting Telescopes for Astrophysical Investigations. *George E. Hale* - - - - - - - - - - - 119
REFRACTOR of the Potsdam Observatory. *H. C. Vogel* - - - - 75
REFRACTING and Reflecting Telescopes for Astrophysical Investigations. *George E. Hale* - - - - - - - - - - 119
ROMAN College Solar Observations during Second Half of 1896. *P. Tacchini* - - - - - - - - - - - - - 159
ROYAL Astronomical Society Gold Medal Awarded to Professor Barnard. *George E. Hale* - - - - - - - - - 215
RUTILE, Vanadium in Scandinavian. *B. Hasselberg* - - - - 194
SHIFT of Spectral Lines, Cause for. *G. F. Fitzgerald* - - - 210
SOLAR Observations during the Second Half of 1896. *P. Tacchini* - 159
SPECTRUM Wave lengths, XVI, p. 11; XVII, p. 109; XVIII, p. 181. *H. A. Rowland*
SPECTRA, Stars Having Peculiar. *E. C. Pickering* - - - 350
Arc, of Cobalt and Nickel. III. *B. Hasselberg* - - - 38
Method of Broadening Stellar. *William Huggins* - - - 8
Mode of Printing Maps of. - - - - - - - - - 216
Of Heavy and Light Helium. *J. S. Ames and W. J. Humphreys* - - - - - - - - - - - - 97
SPECTRAL Lines, Cause for Shift of. *G. F. Fitzgerald* - - - 210
Curvature of. *H. C. Lord* - - - - - - - - 348
New Formula for the Wave-lengths of. *J. J. Balmer* - - 199
SPECTROGRAPHIC Observations of Mars in 1896–7. *James E. Keeler* 328
SPECTROHELIOGRAPH suggested by Mr. H. F. Newall. *George E. Hale* - - - - - - - - - - - - - 211
Correcting Curvature of Lines in. *W. H. Wright* - - - 325
SPECTROSCOPIC, Arendt's Investigations of the Variation of Aqueous Vapor in the Atmosphere. *L. E. Jewell* - - - - - 279
Notes. *W. W. Campbell* - - - - - - - - 233
Binary α^1 Geminorum. *A. Bélopolsky* - - - - - 1
SPECTRUM of ζ Puppis. *E. C. Pickering* - - - - - 92
H. Kayser - - - - - - - - - - - - 95
Of Hydrogen. *H. Kayser* - - - - - - - - 243
Of Mars. *W. W. Campbell* - - - - - - - 235
Wave-lengths, Table of Solar, XVI, p. 11; XVII, p. 109, XVIII, p. 181. *H. A. Rowland*
SPECULA, Support System for Large. *G. W. Ritchey* - - - 143

PAGE

STARS having Peculiar Spectra. *E. C. Pickering* - - - 350
Distribution of, in Clusters. *E. C. Pickering* - - - 352
STARLIGHT, Effective Wave-length of. *George C. Comstock* - - 26
STELLAR Spectra, Method of Broadening. *William Huggins* - 8
SUN, Oxygen in the. *L. E. Jewell* - - - - - - - 99
Arthur Schuster - - - - - - - - - - 162
SUN-SPOTS, Cause of Darkness of. *J. Evershed* - - - - 244
SUPPORT System for Large Specula. *G. W. Ritchey* - - - 143
SURFACES, Steady Liquid. *D. B. Brace* - - - - - - 214
TABLE of Solar Spectrum Wave-lengths, XVI, p. 11; XVII, p. 109; XVIII, p. 181. *H. A. Rowland*
TELESCOPES, Coudé Mounting for Reflecting. *F. L. O. Wadsworth* 132
G. E. H. - - - - - - - - - - - - 148
Refracting and Reflecting for Astrophysical Investigations. *George E. Hale* - - - - - - - - - - 119
TEMPERATURE of an Electric Arc, Effect of Pressure on. *W. E. Wilson and G. F. Fitzgerald* - - - - - - - - 101
THERMAL Measurements with the Bolometer by the Zero Method. *F. L. O. Wadsworth* - - - - - - - - - - 268
TROUVELOT, Sale of Drawings and Instruments from the Collection of the late M. - - - - - - - - - - - 217
VADADIUM in Scandinavian Rutile. *B. Hasselberg* - - - 194
VENUS, Physical and Micrometrical Observations of. *E. E. Barnard* - - - - - - - - - - - - - 299
WAVE-LENGTH of Starlight, Effective. *George C. Comstock* - - 26
WAVE-LENGTHS, Table of Solar Spectrum, XVI, p. 11; XVII, p. 109; XVIII, p. 181. *H. A. Rowland*
New Formula for the, of Spectral Lines. *J. J. Balmer* - - 199
WILCZYNSKI, Remarks on Articles of Mr. E. J. *Paul Harzer* - 36
YERKES Observatory, *George E. Hale*
I. Selection of the Site - - - - - - - - 164
II. The Building and Minor Instruments - - - - 254
III. The Instrument and Optical Shops, and the Power House 310

For titles of Reviews see table of contents.

INDEX OF AUTHORS.

PAGE

AMES, J. S. REVIEW OF:
The Radiations of Uranium and its Salts. Sur diverses propriétés des rayons uraniques, Henri Becquerel - - 66

AMES, J. S., and W. J. HUMPHREYS. On the Spectra of Heavy and Light Helium - - - - - - - - - - - - 97

BALMER, J. J. A New Formula for the Wave-lengths of Spectral Lines - - - - - - - - - - - - - 199

BARNARD, E. E. Note on Professor Campbell's Observations of Nova Aurigae - - - - - - - - - - - 277

Physical and Micrometical Observations of the Planet Venus made with the 12-inch and 36-inch Refractors of the Lick Observatory - - - - - - - - - - - 299

BRACE, D. B. Note on Steady Liquid Surfaces - - - - - 214

BÉLOPOLSKY, A. On the Spectroscopic Binary α^1 Geminorum - 1

CAMPBELL, W. W. Spectroscopic Notes - - - - - - 233

COMSTOCK, GEORGE C. On the Application of Interference Methods to the Determination of the Effective Wave-length of Starlight - - - - - - - - - - - - - - 26

CREW, H., REVIEWS OF:
Ueber die ultravioletten Funkenspectra der Elemente, Franz Exner und E. Haschek - - - - - - - - - 290

Ueber Gesetzmässigkeiten in den Spectren festen Körper, F. Paschen - - - - - - - - - - - - - 60

Experimental Determinations of the Temperature in Geissler Tubes, R. W. Wood - - - - - - - - - 63

Ueber einen Versuch einer electrodynamische Sonnenstrahlung, und über die Aenderung des Uebergangswiederstand bei Berührung zweier Leiter durch electrische Bestrahlung, J. Wilsing und J. Scheiner - - - - - - - - - 219

DORSEY, N. E., REVIEW: Color Photography - - - - - 291

EVERSHED, J. The Cause of the Darkness of Sun-spots - - - 244

FITZGERALD, GEORGE F. Note on a Cause for the Shift of Spectral Lines - - - - - - - - - - - - - 210

FITZGERALD, G. F., and W. E. WILSON. On the Effect of Pressure in the Surrounding Gas on the Temperature of the Crater of an Electric Arc. Correction of Results in Former Paper - - 101

PAGE

FROST, E. B., REVIEW OF:
Die Schwankungen im Wasserdampfgehalte der Atmosphäre auf Grund spectroskopischer Untersuchungen, Th. Arendt - 152
HALE, GEORGE E. On the Comparative Value of Refracting and Reflecting Telescopes for Astrophysical Investigations - - 119
The Yerkes Observatory of the University of Chicago:
I. Selection of the Site - - - - - - - - - 164
II. The Building and Minor Instruments - - - - 254
III. The Instrument and Optical Shops, and the Power House 310
Note on the Ranyard Mounting for Reflecting Telescopes - 148
Note on a Form of Spectroheliograph suggested by Mr. H. F. Newall - - - - - - - - - - - - 211
Award of the Gold Medal of the Royal Astronomical Society to Professor Barnard - - - - - - - - - 215
REVIEWS OF:
Total Eclipse of the Sun, April 16, 1893, J. Norman Lockyer 220
Analyse spectrale directe des Minéraux, Arnaud de Gramont 362
HARZER, PAUL. Remarks on the Articles of Mr. E. J. Wilczynski in this JOURNAL, Vol. IV, No. 2 - - - - - - - - - 36
HASSELBERG, B. Researches on the Arc-Spectra of the Metals. III. Cobalt and Nickel. III - - - - - - - - - - 38
On the Occurrence of Vanadium in Scandinavian Rutile - - 194
HUGGINS, WILLIAM. On an Automatic Arrangement for Giving Breadth to Stellar Spectra on a Photographic Plate - - 8
HUMPHREYS, W. J. and J. S. AMES. On the Spectra of Heavy and Light Helium - - - - - - - - - - 97
JEWELL, LEWIS E. Oxygen in the Sun - - - - - - - - 99
Dr. Arendt's Spectroscopic Investigation of the Variation of Aqueous Vapor in the Atmosphere - - - - - - 279
KAYSER, H. On the Spectrum of Hydrogen - - - - - - 243
On the Spectrum of ζ Puppis - - - - - - - - 95
KEELER, JAMES E. Photographic Studies of the Moon at the Paris Observatory - - - - - - - - - - - - 51
Spectrographic Observations of Mars in 1896–7 - - - 328
REVIEW OF:
Observatory Atlas of the Moon - - - - - - - 150
LORD, H. C. Notes on the Determination of the Focus of an Objective - - - - - - - - - - - - - - 305
Curvature of the Spectral Lines - - - - - - - 348
MENDENHALL, C. E., REVIEW OF:
On a New Photographic Method of Photometry and its Use in the Ultra-Violet. H. Th. Simon - - - - - - - 69

PAGE

MENDENHALL, C. E. REVIEW OF:
1. Anomalous Dispersion Curves of some Solid Dyes, A. Pflüeger; 2. On the Indices of Refraction of Solid Fuchsin, B. Walter; 3. On the Anomalous Dispersion of Absorbing Substances, A. Pflüeger; 4. On the Indices of Refraction of Metals at Different Temperatures, A. Pflüeger - - - 67
MIXTER, GEORGE W., REVIEW: Electro-Magnetic Waves - - 354
PICKERING, E. C. The Spectrum of ζ Puppis - - - - - - 92
Stars having Peculiar Spectra - - - - - - - 350
Distribution of Stars in Clusters - - - - - - - 352
RITCHEY, G. W. A Support System for Large Specula - - - 143
ROWLAND, H. A. Preliminary Table of Solar Spectrum Wavelengths - - - XVI, p. 11; XVII, p. 109; XVIII, p. 181
SCHUSTER, ARTHUR. Oxygen in the Sun - - - - - - - 162
TACCHINI, P. Résumé of Solar Observations made at the Royal Observatory of the Roman College during the Second Half of 1896 - - - - - - - - - - - - - - 159
TODD, D. P. Automatic Photography of the Corona - - - 318
VOGEL, H. C. The Absorption of Light as a Determining Factor in the Selection of the Size of the Objective of the Great Refractor of the Potsdam Observatory - - - - - - - 75
WADSWORTH, F. L. O. Thermal Measurements with the Bolometer by the Zero Method - - - - - - - - - 268
On a New Form of Mounting for Reflecting Telescopes Devised by the late Arthur Cowper Ranyard - - - - - 132
A Note on a New Form of Fluid Prism - - - - - 149
WAIDNER, C. W. REVIEW: Physical Properties of X-Rays - - 282
WILSON, W. E., and G. F. FITZGERALD. On the Effect of Pressure in the Surrounding Gas on the Temperature of the Crater of an Electric Arc. Correction of Results in Former Paper - - 101
WRIGHT, W. H. A Method of Correcting the Curvature of Lines in the Spectroheliograph - - - - - - - - 325
REVIEW OF:
Some Experiments on Helium, Morris W. Travers - - 363
ZEEMAN, P. On the Influence of Magnetism on the Nature of the Light Emitted by a Substance - - - - - - - 332

NOTICE.

The scope of the ASTROPHYSICAL JOURNAL includes all investigations of radiant energy, whether conducted in the observatory or in the laboratory. The subjects to which special attention will be given are photographic and visual observations of the heavenly bodies (other than those pertaining to "astronomy of position"); spectroscopic, photometric, bolometric and radiometric work of all kinds; descriptions of instruments and apparatus used in such investigations; and theoretical papers bearing on any of these subjects.

In the department of *Minor Contributions and Notes* subjects may be discussed which belong to other closely related fields of investigation.

It is intended to publish in each number a bibliography of astrophysics, in which will be found the titles of recently published astrophysical and spectroscopic papers. In order that this list may be as complete as possible, and that current work in astrophysics may receive appropriate notice in other departments of the JOURNAL, authors are requested to send copies of all papers on these and closely allied subjects to both Editors.

Articles written in any language will be accepted for publication, but unless a wish to the contrary is expressed by the author, they will be translated into English. If a request is sent *with the manuscript* twenty-five reprint copies of each paper, bound in covers, will be furnished free of charge to the author. Additional copies may be obtained at cost price. No reprints can be sent unless a request for them is received before the JOURNAL goes to press.

The Editors do not hold themselves responsible for opinions expressed by contributors.

The ASTROPHYSICAL JOURNAL is published monthly except in July and September. The annual subscription price for the United States, Canada and Mexico is $4.00; for other countries in the Postal Union it is 18 shillings. Correspondence relating to subscriptions and advertisements should be addressed to *The University of Chicago, University Press Division, Chicago, Ill.*

Wm. Wesley & Sons, 28 Essex St., Strand, London, are sole foreign agents and to them all European subscriptions should be addressed.

All papers for publication and correspondence relating to contributions and exchanges should be addressed to *George E. Hale, Yerkes Observatory, Williams Bay, Wisconsin, U. S. A.*

GENERAL LIBRARY,
UNIV. OF MICH.
20 MAY 1897

VOLUME V NUMBER 5

THE ASTROPHYSICAL JOURNAL

An International Review of Spectroscopy and Astronomical Physics

MAY, 1897

EDITORS

GEORGE E. HALE
Director of the Yerkes Observatory

JAMES E. KEELER
Director of the Allegheny Observatory

ASSISTANT EDITORS

J. S. AMES
Johns Hopkins University

HENRY CREW
Northwestern University

W. W. CAMPBELL
Lick Observatory

E. B. FROST
Dartmouth College

F. L. O. WADSWORTH, *Yerkes Observatory*

ASSOCIATE EDITORS

M. A. CORNU
École Polytechnique, Paris

C. S. HASTINGS
Yale University

N. C. DUNÉR
Astronomiska Observatorium, Upsala

A. A. MICHELSON
University of Chicago

WILLIAM HUGGINS
Tulse Hill Observatory, London

E. C. PICKERING
Harvard College Observatory

P. TACCHINI
Osservatorio del Collegio Romano, Rome

H. A. ROWLAND
Johns Hopkins University

H. C. VOGEL
Astrophysikalisches Observatorium, Potsdam

C. A. YOUNG
Princeton University

CHICAGO

The University of Chicago Press

WILLIAM WESLEY & SON, 28 Essex St., Strand, London
Sole Foreign Agents

SUBSCRIPTION, FOUR DOLLARS SINGLE NUMBERS, FIFTY CENTS

Copyright 1897 by The University of Chicago

CONTENTS

PHYSICAL AND MICROMETRICAL OBSERVATIONS OF THE PLANET VENUS, MADE AT THE LICK OBSERVATORY WITH THE 12-INCH AND 36-INCH REFRACTORS
E. E. BARNARD 299

NOTES ON THE DETERMINATION OF THE FOCUS OF AN OBJECTIVE - - - - - - - - - H. C. LORD 305

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO. III. THE INSTRUMENT AND OPTICAL SHOPS, AND THE POWER HOUSE - - - - - - GEORGE E. HALE 310

AUTOMATIC PHOTOCRAPHY OF THE CORONA DAVID P. TODD 318

A METHOD OF CORRECTING THE CURVATURE OF LINES IN THE SPECTROHELIOGRAPH - - - - - W. H. WRIGHT 325

SPECTROGRAPHIC OBSERVATIONS OF MARS IN 1896–7
JAMES E. KEELER 328

ON THE INFLUENCE OF MAGNETISM ON THE NATURE OF THE LIGHT EMITTED BY A SUBSTANCE P. ZEEMAN 332

MINOR CONTRIBUTIONS AND NOTES:

Curvature of the Spectral Lines, H. C. LORD, 348. *Stars Having Peculiar Spectra*, EDWARD C. PICKERING, 350.

REVIEWS:

Electro-Magnetic Waves (GEO. W. MIXTER), 354. *Elementary Text-book on Physics*, ANTHONY and BRACKETT (H. C.), 360. *Analyse spectrale directe des Minéraux*, ARNAUD DE GRAMONT (G. E. H.), 362. *Some Experiments on Helium*, MORRIS W. TRAVERS (W. H. WRIGHT), 363.

RECENT PUBLICATIONS: - - - - - - - - 365–370

"A perfect type of the highest order of excellence in manufacture."

Walter Baker & Co.'s

Breakfast

Cocoa

Absolutely Pure.
Delicious.
Nutritious.

COSTS LESS THAN ONE CENT A CUP

Be sure that you get the genuine article, made at

DORCHESTER, MASS.,

By WALTER BAKER & CO., Ltd.

Established 1780.

Won't You?

Dear Bread Makers, see that it is made of the right flour

Everyone now-a-days knows that all but a little bit of the good is bolted out to make flour white.

DO give us wholesome nutritious bread—your baking is simply perfect, bless your hearts, the fault is in the material. Get

The FINE FLOUR of the ENTIRE WHEAT

As ground by the Franklin Mills.

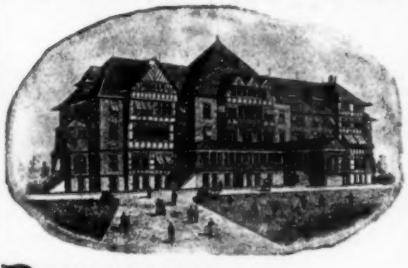
Its value is in its tint—a little off white, rich in Gluten.

If your grocer does not keep it send us his name with your order —we will see that you are supplied.

See that the Flour ordered bears our label; avoid substitutes.

Franklin Mills Co., Lockport, N.Y.

Why Not Recuperate This Spring?



Pennoyer Sanitarium

An ideal, modern home where no expense has been spared in providing every appliance and comfort necessary to make sick people well. Rural surroundings. City advantages. Most healthful locality in America. Distinctive cuisine. Pure water; perfect sanitary conditions. Delightful summer climate. For Illustrated Booklet. Address

N. S. Pennoyer, M. D., Manager,
Kenosha, Wis.

HEALTH! REST! COMFORT!

The Jackson Sanatorium

Dansville, Livingston County, N. Y.

Established in 1858. Most beautiful and commodious Fire Proof Building in the world used as a Health Institution. All forms of Hydro-therapeutics, massage, rest cure; electricity administered by skilled attendants. A staff of regular physicians of large experience; accommodations and service of highest class. Superior cuisine directed by Emma P. Ewing, teacher of cooking at Chautauqua. Do not fail to write for illustrated literature and terms if seeking **health or rest.** Address

J. Arthur Jackson, M.D., Secretary, Box 2003.

GLOBE DESKS AND CABINETS

are built of the choicest materials that can be procured. Finish and workmanship unequalled.

GLOBE FILES.

GLOBE DESKS.

Globe Desks
ARE
Built for Business. Better desks may be built, but better desks never have been built.

Globe Filing Cabinets
contain every improvement and convenience to tempt the most careless into business habits.

THE
GLOBE COMPANY,
CINCINNATI, O.

Eastern Branch: 42 Beaver Street,
NEW YORK.

ILLUSTRATED DESK AND CABINET CATALOGUE FREE.

W. B. Conkey Company

341-351 DEARBORN ST.,
CHICAGO.

Printers,
Binders,
Engravers

PUBLISHERS OF
Hon. William J. Bryan's Great Book,
"THE FIRST BATTLE"

Designers and makers of...
Diplomas, Catalogues, Annuals
Special College Literature

(We refer to the University of Chicago.)

A FIRST CLASS LINE
FOR FIRST CLASS TRAVEL.

Chicago. New York. Boston.

A Summer Note Book

descriptive of the Summer Resorts of the North and East and how to reach them, revised and profusely illustrated, will be sent for 10 cents postage.

City Ticket Office, 119 Adams Street, CHICAGO.

O. W. RUGGLES,
Gen'l Pass'r and Ticket Agent.

SUMMER TOURS
Season of 1897

Grand Trunk Railway System

via the St. Clair Tunnel

NIAGARA FALLS
and the
Rapids of the St. Lawrence
White Mountains
and Seacoast Resorts of the North Atlantic

For Rates, Tickets, or Sleeping-Car Accommodations
Apply to
L. R. MORROW,
City Passenger and Ticket Agent,
103 Clark Street - - CHICAGO

NATURE'S FOOD!

Readshaw's Forest Mills Graham Flour (wheat meal). Made from the choicest selections of Genesee White Winter Wheat, cleansed from all impurities. Rich in Gluten and Phosphates. Used exclusively by the Jackson Sanatorium since 1859. For circulars and price-list, address,

E. H. Readshaw, Dansville, N. Y.

8 BEAUTIFUL ETCHINGS
ILLUSTRATING
AMERICAN SCENERY AND AMERICAN ACHIEVEMENT
ON
"AMERICA'S GREATEST RAILROAD"

An Illustrated Catalogue

Containing miniature reproductions will be sent free post paid on receipt of one 2 ct. stamp, by George H. Daniels, Gen'l. Pass'r. Agt. Grand Central Station, New York.

The University of Chicago Press Publications

ECONOMIC STUDIES

I. **The Science of Finance:** an authorized translation of Gustav Cohn's *Finanzwissenschaft*, by Dr. T. B. Veblen, of The University of Chicago. Large 8vo, cloth, 12 + 800 pages. Price, $3.50 *net.*

II. **History of the Union Pacific Railway.** By Henry Kirke White. Large 8vo, cloth, about 150 pages. Price, $1.50 *net.*

III. **The Indian Silver Currency.** By Karl Ellstaetter. Translated from the German by Professor J. Laurence Laughlin. Large 8vo, cloth, 132 pages. Price, $1.25 *net.*

IV. **State Aid to Railways in Missouri.** By John W. Million, A.M. Large 8vo, cloth, 264 pages. Price, $1.75 *net.*

GERMANIC STUDIES

I. **Der Conjunktiv bei Hartman von Aue.** By Starr Willard Cutting. Paper, 8vo, 54 pages, with 24 inserts of charts and tables. 50 cents.

II. **1. Verner's Law in Gothic. 2. The Reduplicating Verbs in Germanic.** By Frank Asbury Wood. Paper, 8vo, 44 pages. 50 cents.

STUDIES IN ENGLISH

The Assembly of Gods: or, The Accord of Reason and Sensuality in the Fear of Death. By John Lydgate. Edited by Oscar Lovell Triggs. *Volume I. of the English Studies of The University.* Paper, large 8vo, 192 pages, $1.00 *net.*

History of the English Paragraph. By Edwin Herbert Lewis. Paper, 8vo, 200 pages, 50c. *net.*

The Treatment of Nature in English Poetry between Pope and Wordsworth. By Myra Reynolds. Paper, 8vo, 280 pages, 75 cents *net.*

Metaphor and Simile in the Minor Elizabethan Drama. By Frederick Ives Carpenter. Paper, 8vo, 217 pages. 50 cents *net*

MISCELLANEOUS

Assyrian and Babylonian Letters belonging to the K Collection of the British Museum. By Robert Francis Harper, Ph.D., of The University of Chicago.

I. Cloth, 8vo, xv + 116 pages. Price $6.00.
II. Cloth, 8vo, 112 pages. Price $6.00.
III. Cloth (1896), 8vo, xv + 116 pages. Price $6.00.
IV. Cloth (1896), 8vo, xvi + 116 pages. Price $6.00.

The University of Chicago Contributions to Philosophy. Each 35 cents, subscription to four numbers, $1.00.

I. Studies from the Psychological Laboratory.
II. The Necessary and the Contingent in the Aristotelian System. By Wm. Arthur Heidel, Ph.D.

Studies in Classical Philology. Boards, 8vo, 250 pages. $1.50 *net.* Contents of Vol. I.

I. The Anticipatory Subjunctive in Greek and Latin. By William Gardner Hale.
II. Vitruvius and the Greek Stage. By Edward Capps.
III. The Direction of Writing on Attic Vases. By Frank B. Tarbell.
IV. The Oscan-Umbrian Verb System. By Carl D. Buck.
V. The Idea of Good in Plato's Republic. By Paul Shorey.

Studies in Political Science.

I. The Legal Nature of Corporations. By Ernst Freund, J.U.D., of The University of Chicago. Paper, 8vo, 83 pages. 50 cents.

The Negatives of the Indo-European Languages. By Frank Hamilton Fowler. Paper, large 8vo, 40 pages, 50 cents *net.*

An Analysis of the Social Structure of a Western Town. By Arthur W. Dunn. Paper, large 8vo, 53 pages, 25 cents.

Syntax of the Moods and Tenses in New Testament Greek. By Ernest D. Burton, Head Professor of New Testament Literature and Exegesis in The University of Chicago. Second edition, revised and enlarged. Cloth, large 12mo, 22+215 pages. Price, $1.50 *net.*

The Development of the French Monarchy under Louis VI (Le Gros), 1108-1137. By James Westfall Thompson. Paper, 8vo, 114 pages. $1.00 *net.*

Gold and Prices since 1873. By J. Laurence Laughlin. Paper, 8vo, 66 pages, with charts, appendices, and bibliography. Price 25 cents *net.*

Physiological Archives. Hull Physiological Laboratory. I. Publications of year 1895. Paper, 8vo, $1.00 *net.*

The Constitution of the Argentine Republic and the Constitution of the United States of Brazil. By Elizabeth Wallace. Paper, 8vo, 96 pages, 50 cents *net.*

Notes on Mexican Archaeology. By Frederick Starr. Paper, 8vo, 16 pages, with plates, 25 cents *net.*

Phallicism in Japan. By Edmund Buckley. Paper, 8vo, 36 pages, with frontispiece, 50 cents *net.*

Food as a Factor in Student Life. By Ellen H. Richards and Marion Talbot. Paper, 8vo, 28 pages, 25 cents *net.*

All remittances should be made payable to the order of The University of Chicago

The University of Chicago
University Press Division CHICAGO, ILL.

A TYPEWRITER'S CHARM.

"Oh! THAT Easy Touch!"

YOU SIMPLY TOUCH THE KEYS.

THE SMITH PREMIER TYPEWRITER CO.,

SYRACUSE, N. Y., U. S. A.

BRANCH OFFICES IN 23 PRINCIPAL CITIES IN UNITED STATES AND ENGLAND

EASY TOUCH A BIG POINT.

Send for New Ar Catalogue, tree

Strong at Every Point are the NEW MODELS of the Standard Remington Typewriter

NO 6 NO 7

WICKOFF, SEAMANS & BENEDICT
No. 327 BROADWAY
NEW YORK
U. S. A.

CLEVELAND BICYCLES

Makers:

H. A. LOZIER & CO., Cleveland, Ohio.

Our attractive catalog free to prospective buyers.

STERLING CYCLE WORKS

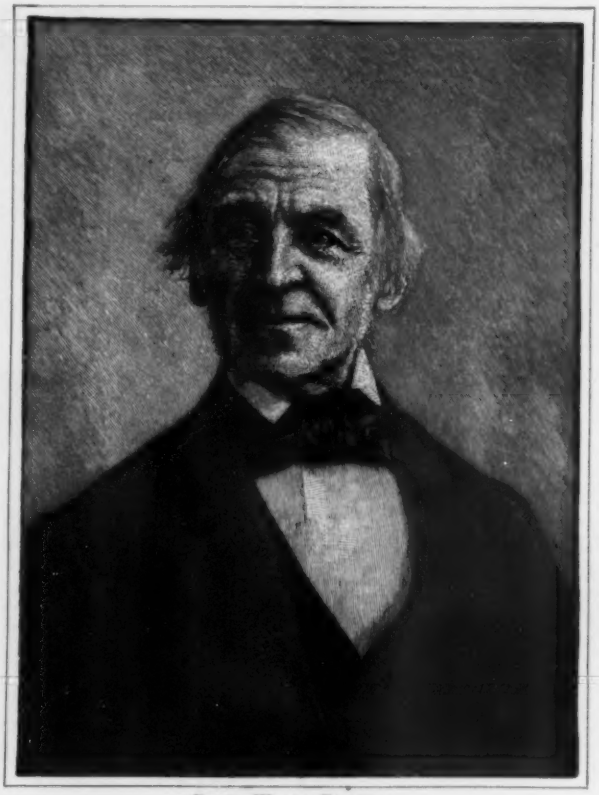
CHICAGO SEND FOR CATALOGUE

"A PROFESSOR OF BOOKS"—EMERSON

In glancing through one of the early volumes of Charles Dudley Warner's "Library of the World's Best Literature," we met, in the Emerson section, an extract from one of the sage's fine pages that ran in this wise:

"Meantime the colleges, whilst they provide us with libraries, furnish no professor of books; and, I think, no chair is so much wanted."

It is doubtful if any phrase could so happily describe at once the function and the achievement of Mr. Warner in his new and great work. He himself is essentially a "professor of books," although the charm of his work has tended to make us forget his wide and varied learning. And knowing not only books but living writers and critics as well, Mr. Warner has gathered around him as advisers and aids other "professors of books," not men of the Dryasdust school, but those who possess the same salient charm and graphic power as himself.



RALPH WALDO EMERSON

The result of this remarkable literary movement has been to provide the great reading public, the busy public of ever scant leisure, with just what Emerson declared more than half a century ago we so much needed, namely, a guide to the best reading.

Emerson indeed likens a library of miscellaneous books to a lottery wherein there are a hundred blanks to one prize, and finally exclaims that "some charitable soul, after losing a great deal of time among the false books and alighting upon a few true ones, which made him happy and wise, would do a right act in naming those which have been bridges or ships to carry him safely over dark morasses and barren oceans into the heart of sacred cities into palaces and temples."

This is precisely what Mr. Warner's new library does in the fine, critical articles which preface the master-works of the greatest writers.

Think what is here accomplished. In the case of Emerson himself, the general voice has proclaimed his two volumes of "Essays" a requisite for every library. But if we have the wish to go farther and know more of the work of our greatest man of letters, what volume shall we select? There are ten or eleven others to choose from. Looking into Mr. Warner's Library we find that Dr. Richard Garnett, of the British Museum, a life-long student and biographer of Emerson, has written a critique that gives us exactly what we wish to know.

Again, take the case of the man who occupies in German life the same place as the Sage of Concord in American life. All told, Goethe's writings comprise seventy compact volumes. Emerson himself, in one of those delightful letters he wrote to Carlyle, tells how, after years of effort, he has "he has succeeded in getting through thirty-five," and despairs of the other half! But who, even among those who call themselves well read, have despatched thirty-five volumes of the great German, or even half or third of thirty-five? Nevertheless,

we do not like to remain without at least a general and historical view of Goethe's tremendous activity, and, furthermore, if we go beyond "Faust" or "Wilhelm Meister," we are—the most of us—lost in a sea of conjecture as to which of the remaining sixty-eight volumes we shall attack.

How happily has Mr. Warner here come to our relief! He has chosen, to prepare the Goethe section for the Library, no less a scholar than Prof. Edwin Dowden of Dublin, the President of the Goethe Society of England. The assignment was most fitting, as no Englishman since Carlyle is so well versed in all that pertains to the great German, none knows better of his strength and power, none better his shortcomings and his weaknesses. Here we have the distilled essence of his criticism, together with Professor Dowden's choice of what is of paramount and lasting value in the legacy Goethe has left to us.

Professor Evans, of Munich, performs for us a like service with Schiller. Prof. Maurice Francis Egan does the same with Calderon. Prof. Charles Eliot Norton of Harvard with Dante. Prof. Santayana with Cervantes. The historian Lecky with Gibbon. Charlton T. Lewis with Bacon, and so on. Never, it seems to us, was so much talent, such an array of eminent names pressed into service for the production of such compact and pregnant exposition and criticism.

It would be a great mistake, however, to believe that the new Library which Mr. Warner and his associates have prepared has to do with nothing but the "classics." Here, for instance, is Dumas the elder. Who is there that has not fallen a victim to the stirring romances of "The Three Musketeers" and their extensive kin? Many of us, when we have once got into their companionship, hardly know where to stop. But we do not want to be misled into reading an immense number of worthless and mediocre stories that Dumas, in the burst of his fame, was led to palm off as his own, though they were in reality the work of others. There never was a more delightful "professor of books" than Andrew Lang, and we doubt if there is any one living who could tell us so much as he has told us in the Library of what is interesting and what we wish to know of Dumas.

We cross from the field of romance over into that of poetry, and the first name we chance upon is that of Wordsworth, one of the greatest poets who ever lived—no one questions that. And yet what great poet ever left so much fine wheat mixed with so much chaff? Dr. R. H. Hutton, the editor of the London *Spectator*, and one of the sanest and most appreciative of living critics, has chosen for this Library the best of Wordsworth's poetry, and has planned such further journeys through the poet's writings as the reader may wish to take.

And so we might go on. But we think we have made clear to the reader that which struck us so forcibly when we looked into the Emerson section, namely, how finely Mr. Warner has, in his Library, succeeded in satisfying the great want which Emerson there so well voiced—that of a "professor of books." Exactly as the professor of chemistry or physics or astronomy or biology gives the student a view of the whole field of his seience, the summary of its achievements, its great names and its great works, so Mr. Warner and his associates have given us the distillation not merely of the whole world's literature, in itself a colossal attempt, but, in addition, its history, biography, and criticism as well. It is only when we grasp its full import that we realize the truly vast and monumental character of the Library. It must assuredly rank as one of the most notable achievements of the century.

That there is a widespread desire among all classes to possess these thirty treasure volumes clearly appears from the number and the character of the letters which are coming from far and near to the Harper's Weekly Club, through which a portion of the first edition is being distributed.

Although the first edition is the most desirable because printed from the fresh, new plates, the publishers, instead of advancing the price, have actually reduced it nearly half, so as to quickly place a few sets in each community for inspection.

The demand for the most desirable first edition is so active and the number of sets allotted to be distributed is so limited, it is safest for those who really covet this invaluable Library of Mr. Warner's to write at once to Harper's Weekly Club, 91 Fifth Avenue, New York, for sample pages and special prices to members of the Club now forming, and which will close the last day of the present month.

A Novel Educational Competition

Combines pleasure with information and mental training

The Century Co. announces an educational competition which it is hoped will arouse very general interest. Three examination papers, each containing fifty questions have been prepared; the competitors have a month to answer each set. The prizes are as follows: $500 to the person sending in the best set of answers, $100 for the second best, $50 for the third, two of $25 each for the fourth and fifth, and thirty of $10 each for the next thirty in order of merit. There is also another and special offer of $500.

THE QUESTIONS in these examination papers are based on the supposition that a public school graduate of average intelligence can score 75 per cent. if he gives ten minutes of serious application to each question. Anyone, therefore, who devotes to them three hours a week should make a better score, and stand an excellent chance of winning a prize.

Pleasure and Education Combined

The aim of the questions is to impart knowledge and to lead to a habit of investigation that will be of value through life. This they do in an astonishing degree. If you gain first prize, the knowledge you have acquired will be worth more to you than the $500 you receive. But whether you win that prize or not, you learn to concentrate your mind, sharpen your wits, and secure most valuable information.

Do not cease your education when you leave school or college; keep on learning. Horace Greeley said of Lincoln that his success lay largely in the fact that every day he lived he acquired new knowledge and therefore broadened. Get the information that is in these questions. They are not the kind that are found in school-books; they deal with facts that men, women, boys, and girls ought to know. No university extension lectures, no course of reading can help you as these questions do, because the lectures and the reading deal with theoretical knowledge, these questions with practical everyday knowledge.

University Extension Surpassed

Dumb-bells and bicycles may be equally useful in physical development, yet a thousand persons ride their wheels for one that uses dumb-bells. The reason is perfectly evident. Bicycle riding combines pleasure with exercise; the use of dumb-bells is drudgery. So with these questions; they combine pleasure with mental exercise. You cannot start work on the first one without continuing on to the last, and when you finish them you find that you are repaid a hundredfold.

An analysis of the first fifty questions shows that they deal with or touch upon a very large number of different and distinct points or bits of knowledge. That is, in answering fifty questions, you have investigated fifty subjects, and, in addition, have touched upon hundreds of others. History and literature, the Bible and Homer, travel, machinery and law, operas and music, Shakspere and Scott, Paris and Boston, art and architecture, grammar and arithmetic, earthquakes and the heavens, cards and the stage, Napoleon and the North American Indians, the Amazon and the Mississippi, gold-mining and puddling, questions of home and of business—all these and a multitude of others are covered by these questions. Thus, in addition to the pleasure and the mental training, comes the new knowledge that will broaden you as Greeley said it broadened Lincoln. On request, we will forward you sample questions and full particulars of the competition.

$500.00 First Prize

If you do not possess a set of The Century Dictionary and Cyclopedia, address us and we will send your name to one of the few clubs that are still being formed, each member of which secures a set at a reduction of over 40 per cent. and has the privilege of paying for it in small monthly payments. Address:

The Century Co. (Dept. Kw), New York

THE SUMMER QUARTER

OF

The University of Chicago

WILL OPEN JULY 1, 1897.

This Quarter is an integral part of the scholastic year, and is divided into two terms of six weeks each.

Two hundred and twenty courses of Instruction in Philosophy, Pedagogy, Political Science, History, Sociology, Comparative Religion, Hebrew, Assyrian, Arabic, Egyptian, Old Testament Literature and History, New Testament Literature and History, Comparative Philology, Greek, Latin, Romance Languages and Literatures, Germanic Languages and Literatures, English, Mathematics, Astronomy, Physics, Chemistry, Geology, Zoölogy, Anatomy and Histology, Bacteriology, Palæontology, Botany, Public Speaking, Systematic Theology, Church History, Homiletics, and Physical Culture.

Instruction will be given by one hundred and one Professors and Instructors. All the Libraries, Laboratories, and Museums of The University will be open.

Expenses, including Tuition, for a term of Six Weeks, need not exceed $50.00, and may be less.

For circulars and information address,

THE EXAMINER,

THE UNIVERSITY OF CHICAGO, CHICAGO, ILL.

A Charming Book About Old Violins.

Violinists everywhere will hail with delight the beautifully printed and authoritatively written book about Old Violins, just published by Lyon & Healy, Chicago. The fact that this volume contains, as an appendix, a list of the old violins offered for sale by Lyon & Healy, does not detract from its literary value, It is safe to say that any lover of the fiddle might seek a long time before he could find another volume whose perusal would afford him such a fund of entertainment. The short biographies of the famous violin makers are wonderfully complete and comprise a host of fresh anecdotes that must prove vastly interesting to violinists, great and small.

("OLD VIOLINS"—272 PAGES—FREE TO VIOLINISTS ONLY. LYON & HEALY, CHICAGO.)

THE MORGAN PARK ACADEMY

OF

The University of Chicago.

A thorough preparatory school for both sexes. Twelve teachers, all specialists and college graduates. Eight buildings, athletic field, gymnasium. Library of 4000 volumes. Delightful situation, near enough the city for Chicago students to spend Saturday and Sunday at home. Preparation for The University of Chicago and all other Colleges and Universities. Life in houses under teachers' supervision. Introductory year for young pupils.

For Calendar and full information address

CHARLES H. THURBER, Dean,
Morgan Park, Ill.

Wanted

Copies of

The . . .

Astrophysical Journal

For

MARCH 1895

One Dollar each will be paid for clean and perfect copies of the above issue.

Address . . .

GEORGE E. HALE
Yerkes Observatory
Williams Bay, Wisconsin, U. S. A.

THE

AMERICAN JOURNAL

OF

SOCIOLOGY

CONTENTS FOR MAY 1897.

Insurance against non-Employment — Paul Monroe
Some Economic Losses in the Building Trades — S. T. Wood
The Present Status of Sociology in Germany. III. — O. Thon
Individual Telesis — Lester F. Ward
Social Control. VII. — E. A. Ross
Some Demands of Sociology upon Pedagogy — Albion W. Small
A Programme for Social Study — I. W. Howerth
Reviews — Notes and Abstracts — Bibliography — Index to Vol. II.

$2.00 per Year - - 35 Cents per Copy

Volume II, over 900 Pages

Address **The University of Chicago,**
University Press Division, Chicago, Ill.

Save Time Pen

You write with an ordinary pen:

Dips per letter	30
Letters per day	10
Total letter dips	300
Extra dips for extra work	280
Total dips per day	580
" " " week	3,480
" " " year	180,960

A second to a dip:

Minutes wasted per year	3,016
Hours " " "	50

A whole week's working time wasted.

Guess you'd better buy a Waterman Ideal Fountain Pen. Sold everywhere.

L. E. Waterman Co.,
157 Broadway, New-York.

VOLUME IV NUMBER 5

THE PHYSICAL REVIEW

A JOURNAL OF EXPERIMENTAL AND THEORETICAL PHYSICS

CONDUCTED BY
EDWARD L. NICHOLS
ERNEST MERRITT, AND FREDERICK BEDELL

XXIII

MARCH–APRIL 1897

TABLE OF CONTENTS

The Lead Cell B. E. MOORE 353

The Influence of a Static Charge of Electricity upon the Surface Tension of Water E. L. NICHOLS and J. A. CLARK 375

On the Mechanical Conceptions of Electricity and Magnetism W. S. FRANKLIN 388

Monr Contributions: On a Possible Development of the Idiostatic Electrometer; *C. Barus.* Empirical Formulæ for Viscosity as a Function of Temperature; *A Wilmer Duff.* A Synchronous Motor for Determining the Frequency of an Alternating Current; *G. S. Moler.* Lecture-room Demonstration of Orbits of Bodies under the Action of a Central Attraction; *R. W. Wood.* The Refractive Index of Water and Alcohol for Electrical Waves; *A. D. Cole* 400

New Books: *Merriman and Woodward:* Higher Mathematics. *Hathaway:* A Primer of Quaternions. *D. C. and T. C. Jackson:* Alternating Current Machinery. *Kapp:* Transformers for Single and Multiphase Circuits. *Brentano:* Méthode et Principes des Sciences Naturelles. *Le Blanc:* Elements of Electro-Chemistry. *Carter:* Motive Power and Gearing for Electrical Machinery. Mathematical Papers read at the International Mathematical Congress, Chicago, 1893. *Williams:* Laboratory Manual of Inorganic Chemistry. *Tuttle:* Chemistry at a Glance. *Thorp:* Inorganic Chemical Preparations. The American Annual of Photography. *Matthews and Shearer:* Problems and Questions in Physics. 416

COPYRIGHT, 1897, BY THE MACMILLAN COMPANY.

PUBLISHED FOR CORNELL UNIVERSITY
NEW YORK: THE MACMILLAN COMPANY
LONDON: MACMILLAN & CO., LTD.
BERLIN: MAYER & MUELLER

THE JOURNAL OF PHYSICAL CHEMISTRY

Edited by
Wilder D. Bancroft, Joseph E. Trevor

Published at
Cornell University

RECENT ARTICLES

On Irreversible Cells. I.	*A. E. Taylor*
Chemistry and Its Laws	*F. Wald*
On Ternary Mixtures	*W. D. Bancroft*
Allotropy of Sucrose	*F. G. Wiechmann*
Nascent Hydrogen	*R. Franchot*
On Irreversible Cells. II.	*A. E. Taylor*
Purification of Water	*G. A. Hulett*
Solution and Fusion	*W. D. Bancroft*
Speed of Esterification	*R. B. Warder*
Precipitation of Salts	*H. A. Bathrick*
Inner Thermodynamic Equilibria	*J. E. Trevor*
The Abegg Method, *etc.*	*E. H. Loomis*
Sulfur and Toluene	*J. K. Haywood*
On the Liquefaction of a Mixture of two Gases	*P. Duhem*
Mercuric Chlorid	*D. McIntosh*
Mass Law Studies. I.	*S. F. Taylor*
On Quintuple Points	*W. D. Bancroft*
Solids and Vapors. Second Paper	*W. D. Bancroft*
Osmotic Pressure and Variance	*J. E. Trevor*
Distillation with Vapor	*C. H. Benedict*
A Triangular Diagram	*W. D. Bancroft*
Cuprous Chlorid	*J. K. Haywood*
Two Liquid Phases. First Paper	*W. D. Bancroft*

In addition to the original articles each number contains critical reviews of the current journal and book literature of Physical Chemistry.

ITHACA, NEW YORK: The Editors

LONDON: Gay and Bird **LEIPZIG: Bernh. Liebisch**

Issued every month, except July, August, and September.

Price, $2.50 per year.

The first volume will run to the close of 1897, and comprise twelve numbers

RECENTLY PUBLISHED

The Natural History and Scientific Book Circular
No. 124

ASTRONOMY

Including Works from the Libraries of

SIR G. B. AIRY, F.R.S., late Astronomer Royal

and

A. C. RANYARD, F.R.A.S., Editor of Knowledge

A new and valuable catalogue of astronomical and astrophysical works. To be had on application to

WILLIAM WESLEY & SON,

Agency of the Smithsonian Institution
U. S. Government Departments.

28 ESSEX STREET, STRAND, LONDON.

The
School Review
A Journal of Secondary Education
Edited by CHARLES H. THURBER

CONTENTS FOR APRIL 1897:

Secondary Education in the United States. Elmer E. Brown
What Studies should Predominate in Secondary Schools? A. F. Nightingale
Higher Education in the North Central States. C. K. Adams
Discipline vs. Dissipation in Secondary Education. Paul Shorey
Outlook Notes. C. H. Thurber
The Holiday Conference of 1896. F. D. Boynton
Correspondence;
The Psychology of the Diagram. F. A. Barbour
Change in Entrance Requirements to Vassar College J. M. Taylor
Notes.
New Publications.

The School Review is the official organ of the Michigan Schoolmasters' Club; has full reports of the proceedings of that organization, as well as reports of the N. E. A. and other educational associations contained in four special numbers each year.

Subscription price, $1.50 per year. Published monthly except in July and August. Single copies 20 cents. Samples free on request to

THE UNIVERSITY OF CHICAGO
University Press Division - - - CHICAGO, Ill.

LOUIS MÜLLER-UNKEL,
(Partners: L. Müller-Unkel and R. Müller-Uri)
BRAUNSCHWEIG, GERMANY

MANUFACTURERS OF

Blown Glass
For Scientific Purposes

All kinds of Lecture Apparatus and Supplies
Lecher's and Zehender Tubes, etc.
For Hertz's Experiments
Lenard's Tube
For Kathode Rays
Röntgen's X Rays Apparatus
(Latest Improved Style)
Plucker's Spectrum Tubes and Geissler Tubes
Elster and Geitel's Apparatus
For Tela's Experiments

SOLE MAKERS OF

ELSTER & GEITEL'S PHOTO-ELECTRIC APPARATUS, etc.

Photographs, Bromide Enlargements, Lantern Slides, and Window Transparencies.

From recent Astronomical Negatives made by

Professors George E. Hale,
E. E. Barnard, and
S. W. Burnham,

including all that will be made at the

YERKES OBSERVATORY

Sun-Spots, Faculæ, Solar Prominences,

From negatives made with the

Spectroheliograph at the Kenwood Observatory

Stellar Spectra and the Spectra of various Solar Phenomena

Professor Barnard's Photographs of Comets, Nebulæ, and the Milky Way

Professor Burnham's Negatives of the Moon, Winter and Summer Views of Mt. Hamilton and Lick Observatory

Lantern-Slides furnished from any of the plates, diagrams, etc., published in this journal

Price of Lantern-Slides 75 cents each

Catalogue and Price List mailed on application

Chicago Institute of Photography

308-316 Dearborn Street

GAYTON A. DOUGLASS
Director

CHICAGO

JOHN BYRNE'S

Astronomical and Terrestrial

TELESCOPES

Of three, four, five, six inches and larger apertures

Short Focus and Brilliant Light

Inimitable for Perfection of Figure, Sharpness of Definition, and Accuracy of Color Correction. Send for Catalogue to

GALL & LEMBKE

Opticians

21 Union Square, New York City

The treatment consists of douches, showers, needle baths, and the water-cure treatment; galvanic, faradaic and static electricity; massage and muscle beating; Isopathy (animal extracts), and the necessary medicines; in fact, all recognized scientific methods for the cure of disease.

THE WASHINGTON SANITARIUM,

WASHINGTON, D. C.

The Medical Director is Dr. Mahlon Hutchinson, of the former well-known Hammond Sanitarium. The Medical Staff consists of six physicians, of national reputation in their several specialities. At the Country Branch there are Tennis Courts, Bowling Alley, etc., for the amusement of convalescents.

Special attention paid to the treatment of **DISEASES OF THE NERVOUS SYSTEM AND OF THE SKIN.** Charges moderate. **For full information and pamphlet,** Address

DR. MAHLON HUTCHINSON, 720 Fourteenth St., Washington, D. C.

THE WASHBURN BOOK ABOUT MANDOLINS AND GUITARS.

Any one interested in the subject of mandolins and guitars can obtain a beautiful book about them free by writing to Lyon & Healy, Chicago. It contains portraits of over 100 leading artists, together with frank expressions of their opinion of the new 1897 model Washburn Instruments. Descriptions and prices of all grades of Washburns, from the cheapest ($15.00) upwards, are given, together with a succinct account of the points of excellence which every music lover should see that his mandolin or guitar possesses. Address, Dept. M, LYON & HEALY, 199 Wabash Avenue, Chicago.

THE WESTON STANDARD

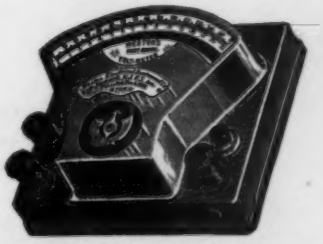
VOLTMETERS & AMMETERS

Portable,

Accurate,

Reliable and

Sensitive.



WESTON ELECTRICAL INST. CO.,

114 WILLIAM ST., NEWARK, N. J.

ALVAN CLARK & SONS

CAMBRIDGEPORT, MASS.

Manufacturers of

ASTRONOMICAL TELESCOPES

With Improved Equatorial Mountings

Sizes from Four-inch Aperture
to the Largest Ever Ordered

Send for Photographs of our Portable Equatorials or five and six-inch fixed, with accessories — the best to be had for educational and amateur work.

Terrestrial Telescopes for private residences.

The performance of our instruments, famous the world over, is their own greatest recommendation. An experience of nearly a half century in the art of telescope making enables us to apply a degree of skill and judgment to our work which make our objectives **unrivalled in excellence.**

Among our telescopes are

The Lick Refractor, 36-inch.
Pulkowa Refractor, 30-inch.
Washington Refractor, 26-inch.
University of Virginia, 26-inch.
Princeton Refractor, 23-inch.
Denver Refractor, 20-inch.
Chicago Refractor, 18.5-inch.
Rochester Refractor, 16-inch.

Most Modern and Complete
Illustrating and Engraving Establishment in America

Binner's
"Modernized Advertising"
sent on receipt of 10 cents postage
Illustrated from cover to cover.

Binner's
Poster
mailed to any address on receipt of 10 cents U. S. postage.

Illustrators and Engravers for
Scientific Reports and Publications, College Annuals, Souvenirs, Medical Books, Etc.,
Either in black and white or colors

Binner, in the Fisher Building, **Chicago,** Ill

John A. Brashear

ASTRONOMICAL AND PHYSICAL INSTRUMENTS

Allegheny, Pennsylvania

ASSOCIATES:
Dr. Charles S. Hastings
James B. McDowell
Charles H. Brashear

CABLE ADDRESS:
Brashear, Pittsburg

Manufacturers of

Refracting and Reflecting Telescopes, for visual and photographic purposes.

Objectives all computed by our associate, DR. CHARLES S. HASTINGS, and rigorously treated for all corrections.

Wide field Photographic Doublets, giving circular images of stars up to edge of field.

Plane Mirrors of Speculum Metal, Steel or Glass. Parallel Plates. Prisms of Glass, Quartz or Rock Salt, with surfaces accurately flat.

Eyepieces of any description.

Diffraction Gratings ruled on PROFESSOR ROWLAND'S Engine, from one to six inches in diameter.

Spectroscopes of all kinds, including various forms of Telespectroscopes, Spectroheliographs Concave Grating Spectroscopes, Spectrometers etc., for visual and photographic work.

Comet "Sweepers," Micrometers, Driving Clocks, Heliostats, Siderostats, Refractometers, etc., etc.

SPECIAL APPARATUS

For Astronomical and Physical Research Designed and Constructed

Pond's Extract

FOR
BRUISES,
SPRAINS,
BURNS,
SORE FEET,
PILES,
CHAFING,
SORE EYES.

CATARRH,
HOARSENESS,
SORE THROAT,
NEURALGIA,
TOOTHACHE,
DIARRHŒA,
Etc., Etc.

Caution.—POND'S EXTRACT has been imitated. The genuine has the words "POND'S EXTRACT" blown in the glass, and our label-*Kaxpe*, trade mark on surrounding buff wrapper. Take no other preparation.

Have you heard
play the ÆOLIAN . .
PIPE ORGAN in the
Great Northern Hotel,
Chicago, erected by
Farrand & . . .
Votey Organ . .
Co., Detroit? .

Are you interested in
up-to-date Pipe Organs,
embodying in their con-
struction the latest ap-
plications of electric and
pneumatic powers?

If so, your address please.

FUN MAKING

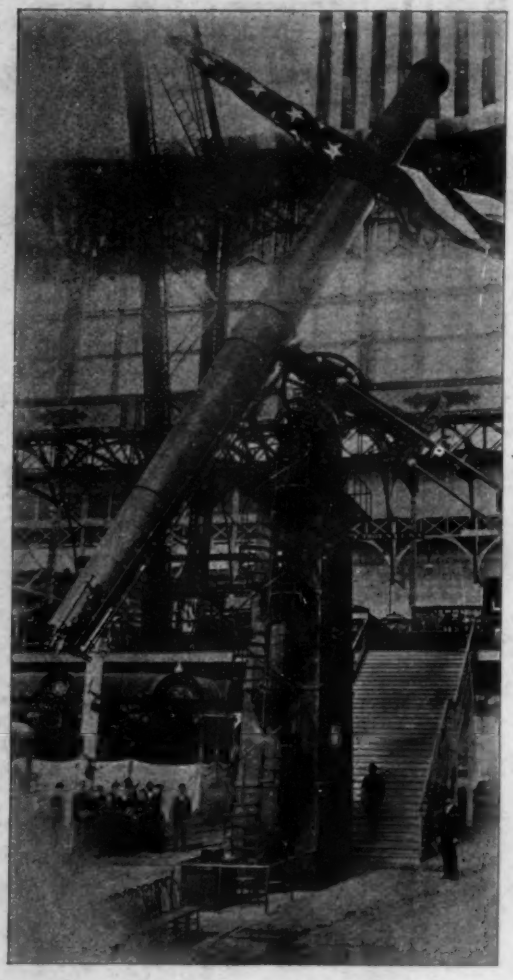
and health making are included in the making of HIRES Rootbeer. The preparation of this great temperance drink is an event of importance in a million well regulated homes.

HIRES
Rootbeer

is full of good health. Invigorating, appetizing, satisfying. Put some up to-day and have it ready to put down whenever you're thirsty.

Made only by The Charles E. Hires Co., Philadelphia. A package makes 5 gallons Sold everywhere.

Astronomical Instruments



40-in. Yerkes Telescope at Columbian Exposition

Equatorial Telescopes

Zenith Telescopes

Alt-Azimuth Telescopes

Meridian Circles

Transits

Chronographs

We have in process of construction a complete line of standard telescopes for educational institutions and private observatories.

WARNER & SWASEY

CLEVELAND, OHIO, U. S. A.

al